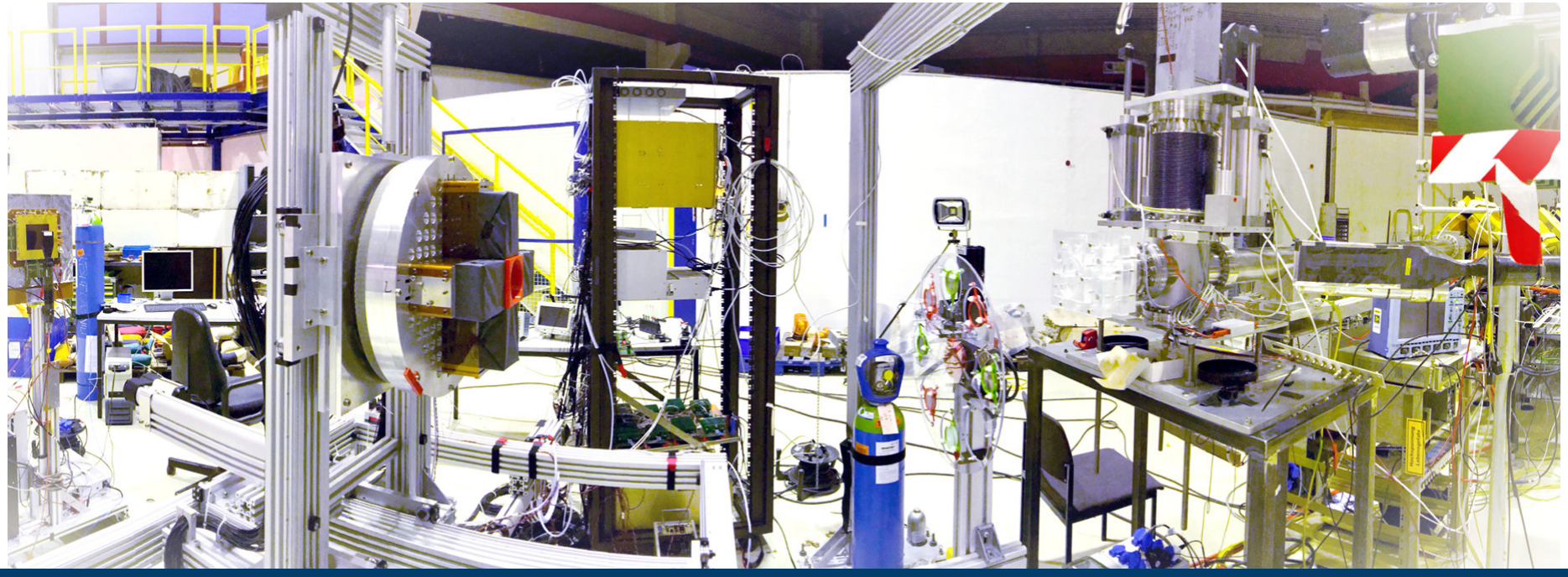

TOWARDS THE EDM POLARIMETRY

Spokespersons: I. Keshelashvili, D. Mchedlishvili, B. Lorentz

CBAC 2018 #8 | Exp. No.: E002.6

July 2nd, 2018 | Irakli Keshelashvili | IKP-2

OUTLINE

Introduction

→ *Future goals: Polarimeter at ANKE target station*

Experiment

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→ Temperature monitoring

→ Lab test of all modules

→ Detector preparation

→ Pol. mechanic

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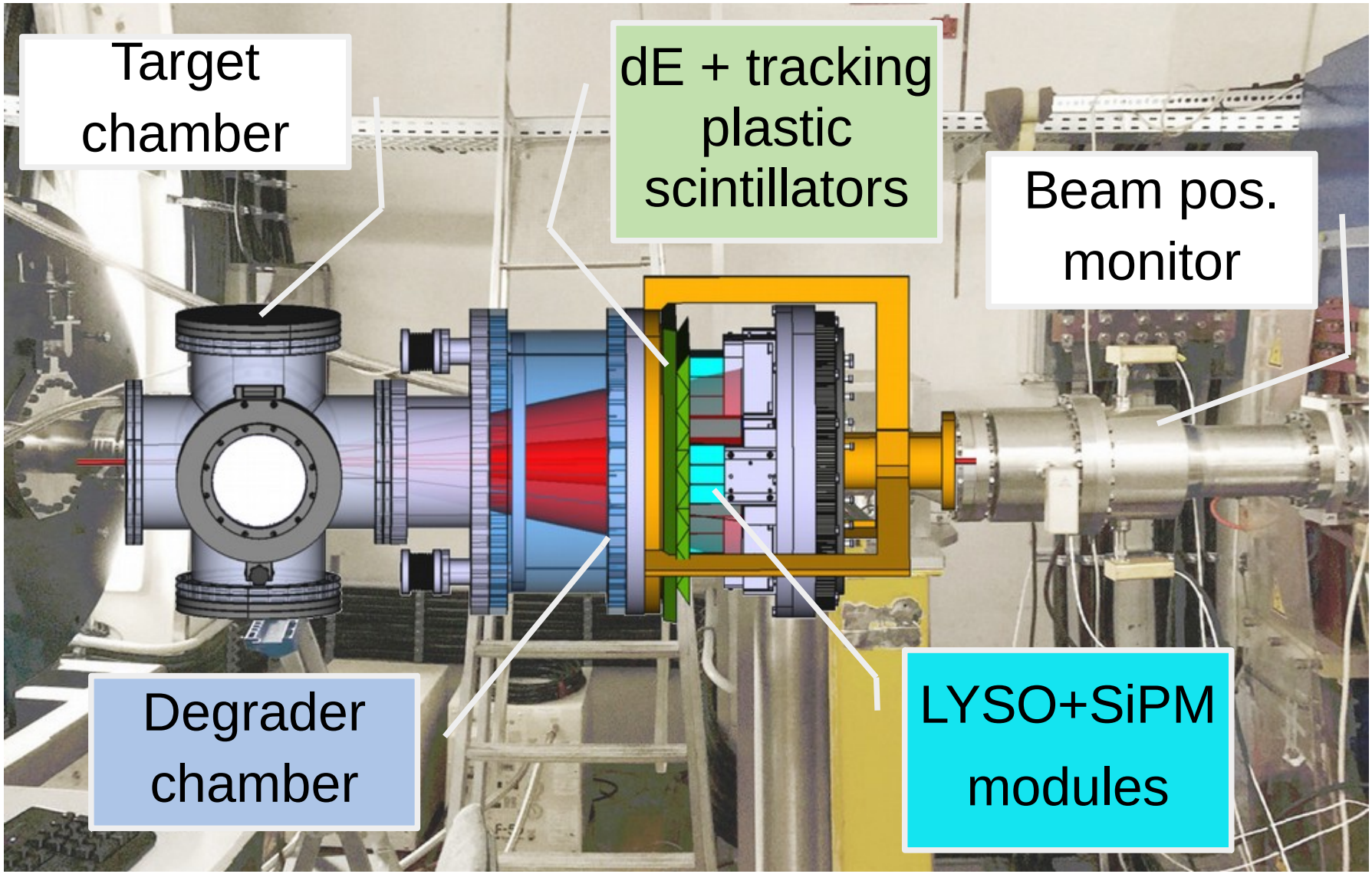
S u m m a r y

→ Beam time: last measurement with extracted beam

PLAN FOR 2019: JEDI POLARIMETER @ ANKE



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during the March 2018 **1 week** beam time

Expected conditions

- 1 week of beam time instead of 2 (from **March 2 to 14**, including MD)

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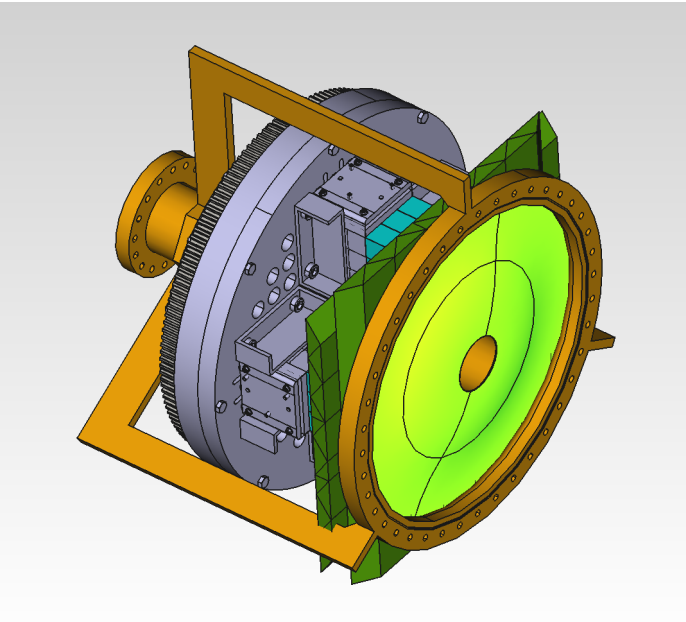
- Because of low polarization in one state, from the beginning we decided to start with unpolarized one. Unfortunately, the polarized source got unexpected problems...
- Due to 3D printing failure; exit window delivery problem; FADC synchronization issues, we faced difficulties...

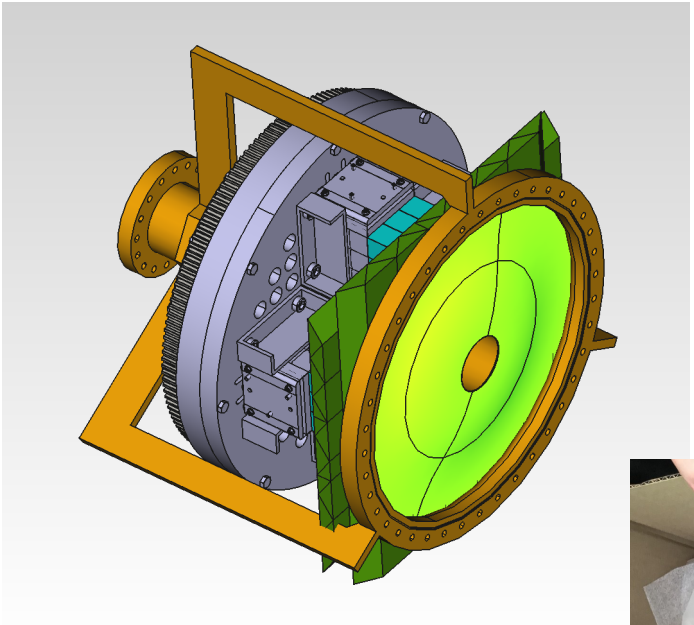
Beam time preparation

EXIT WINDOW



Our plan was to test
fully assembled forward
forward part of
the polarimeter

EXIT WINDOW

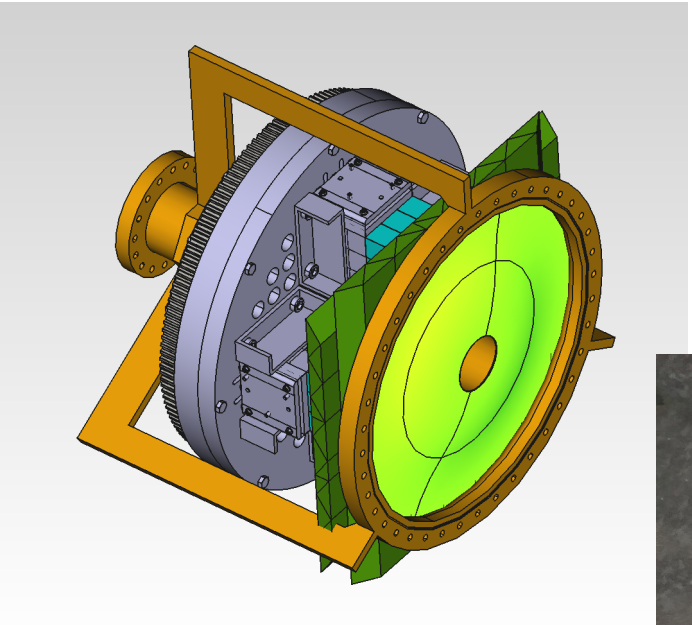


2 month delayed delivery

and surprise from

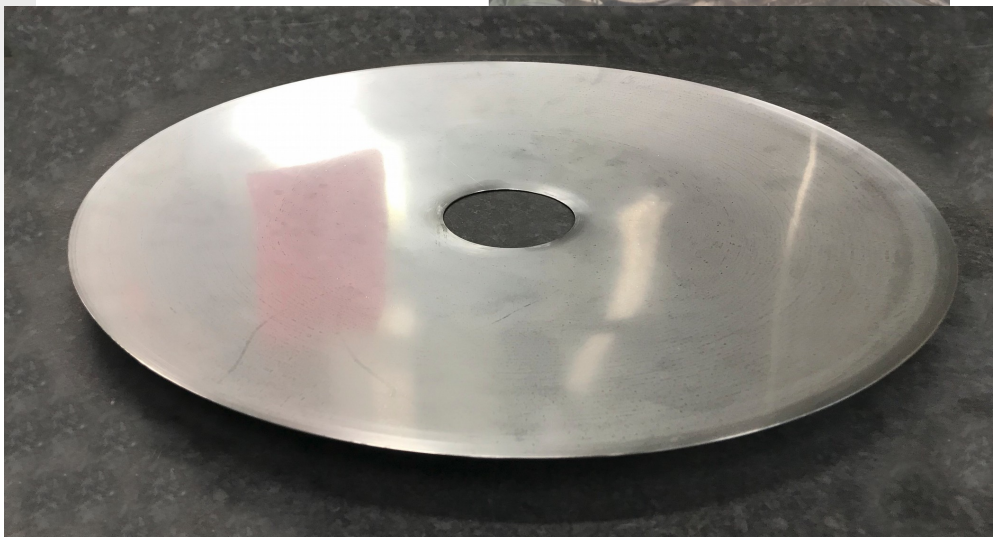
unknown company

EXIT WINDOW



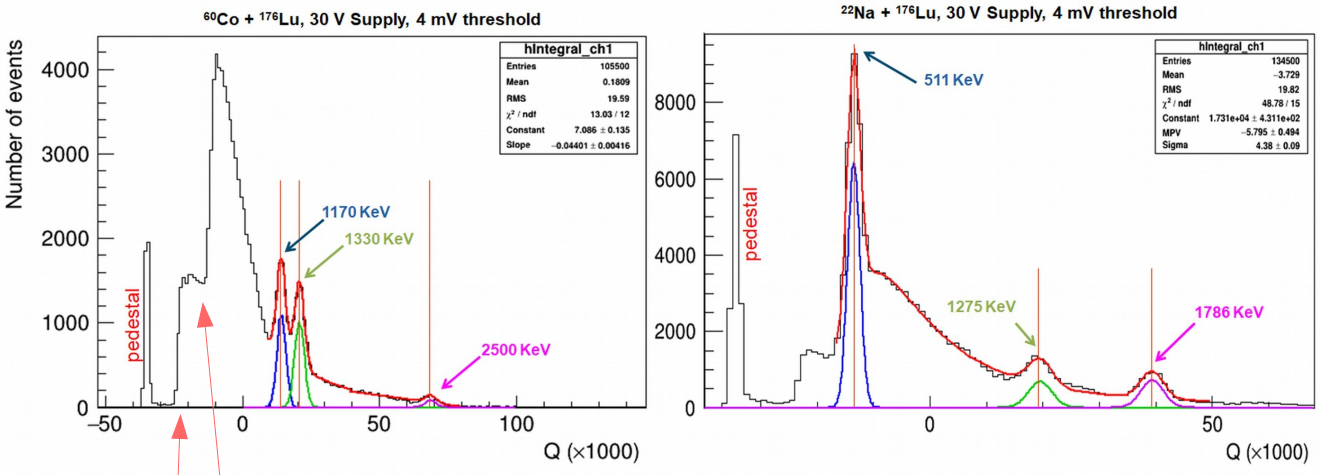
Delivered

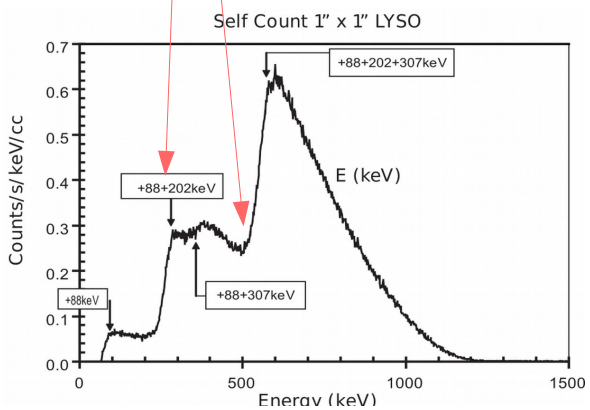
1 week ago



LABORATORY TEST

Before installation all 52 LYSO-SiPM modules where tested...
2 modules reassembled with Ketek 15μm pixel sensor...





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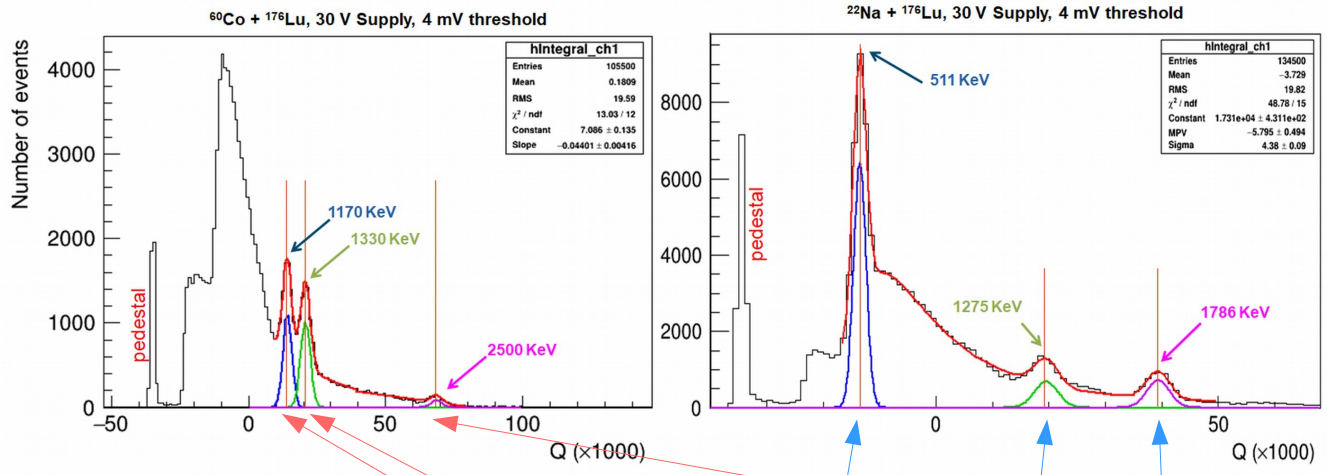
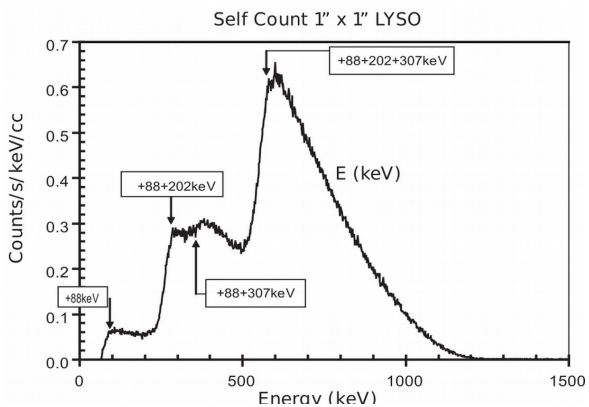
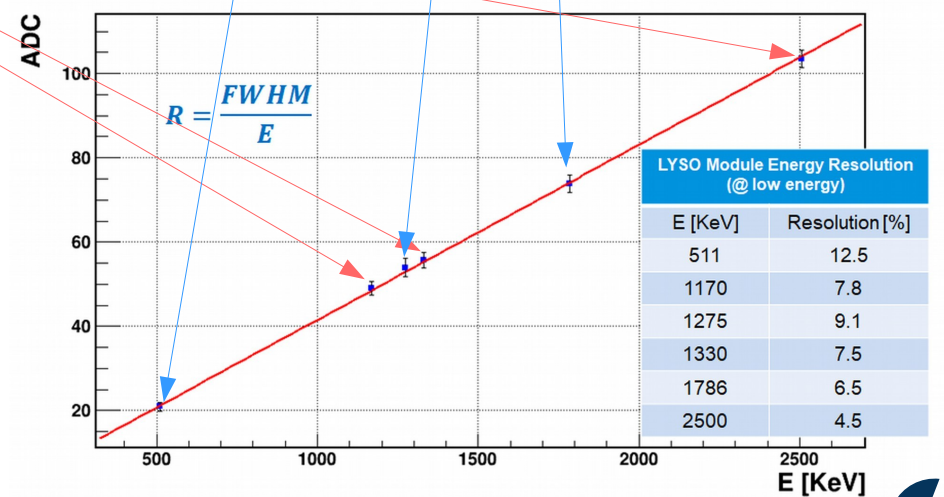






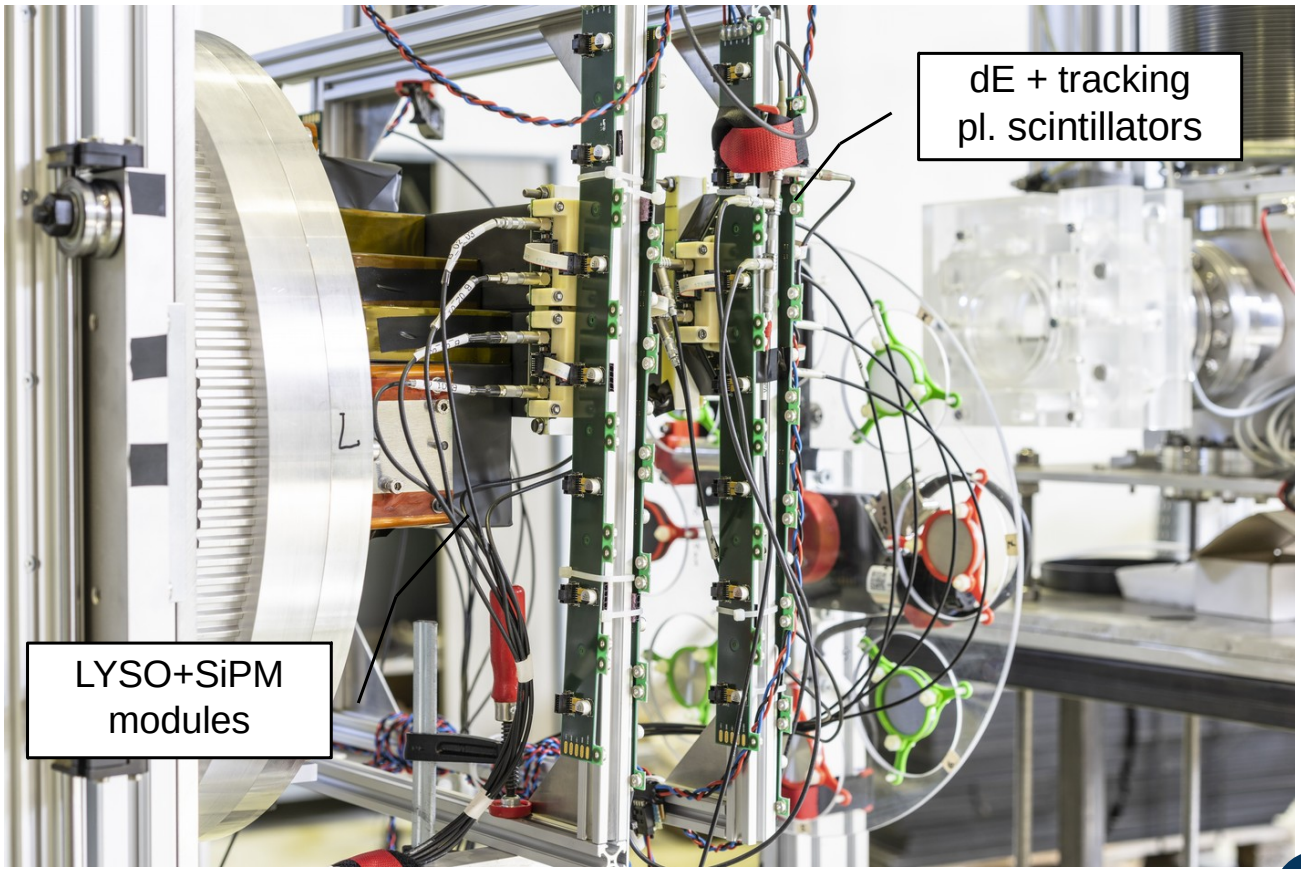
LYSO Module Energy Resolution (@ low energy)	
E [KeV]	Resolution [%]
511	12.5
1170	7.8
1275	9.1
1330	7.5
1786	6.5
2500	4.5

POLARIMETER SETUP FOR MARCH 2018

Setup, similar to last beam time.

In addition to the last setup, six triangular plastic scintillator bars, three per plane, are used.

The 2D scans of LYSO modules and the relative position scan for the plastic scintillators were made using this setup.

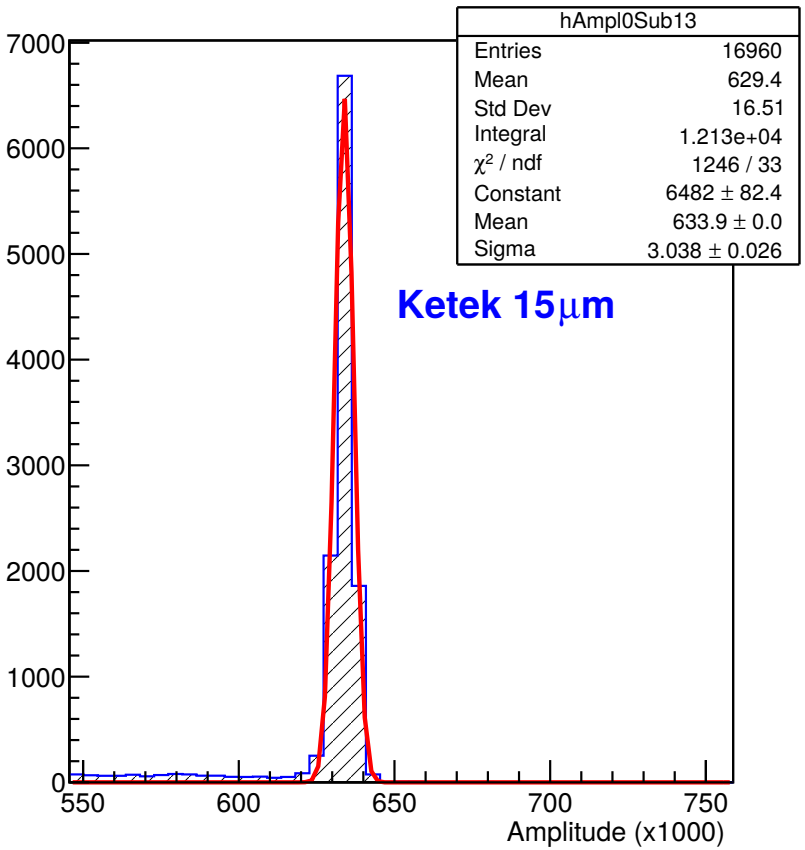


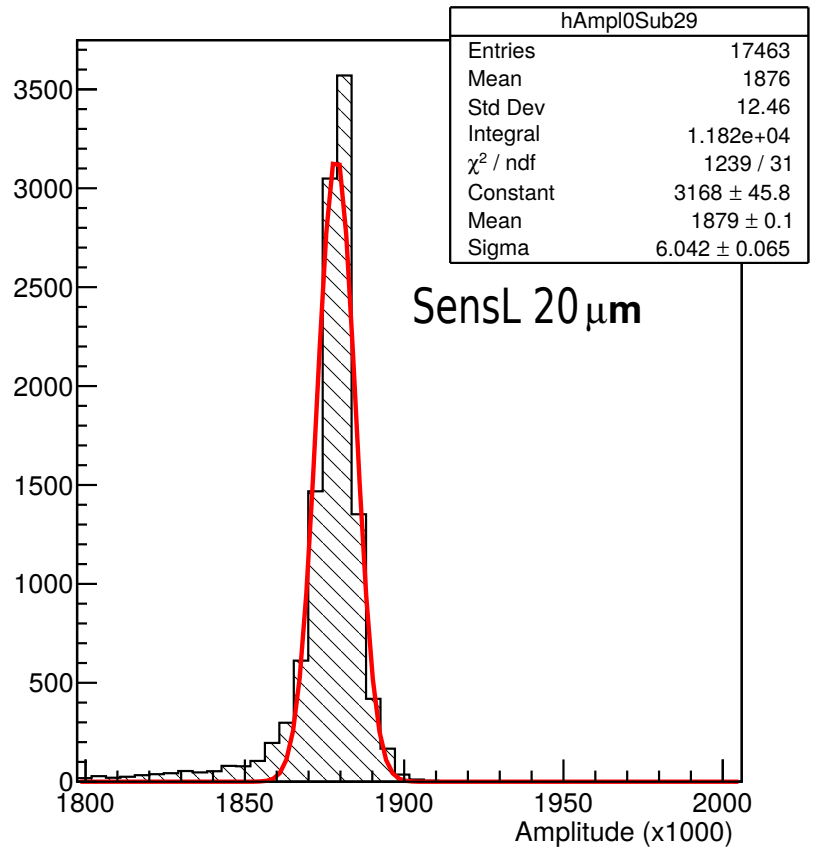
Ketek *vs.* **SensL**

KETEK VS SENSL

A typical charge distribution spectra at 200*MeV* deuteron beam energy aimed at the middle point of a crystal.

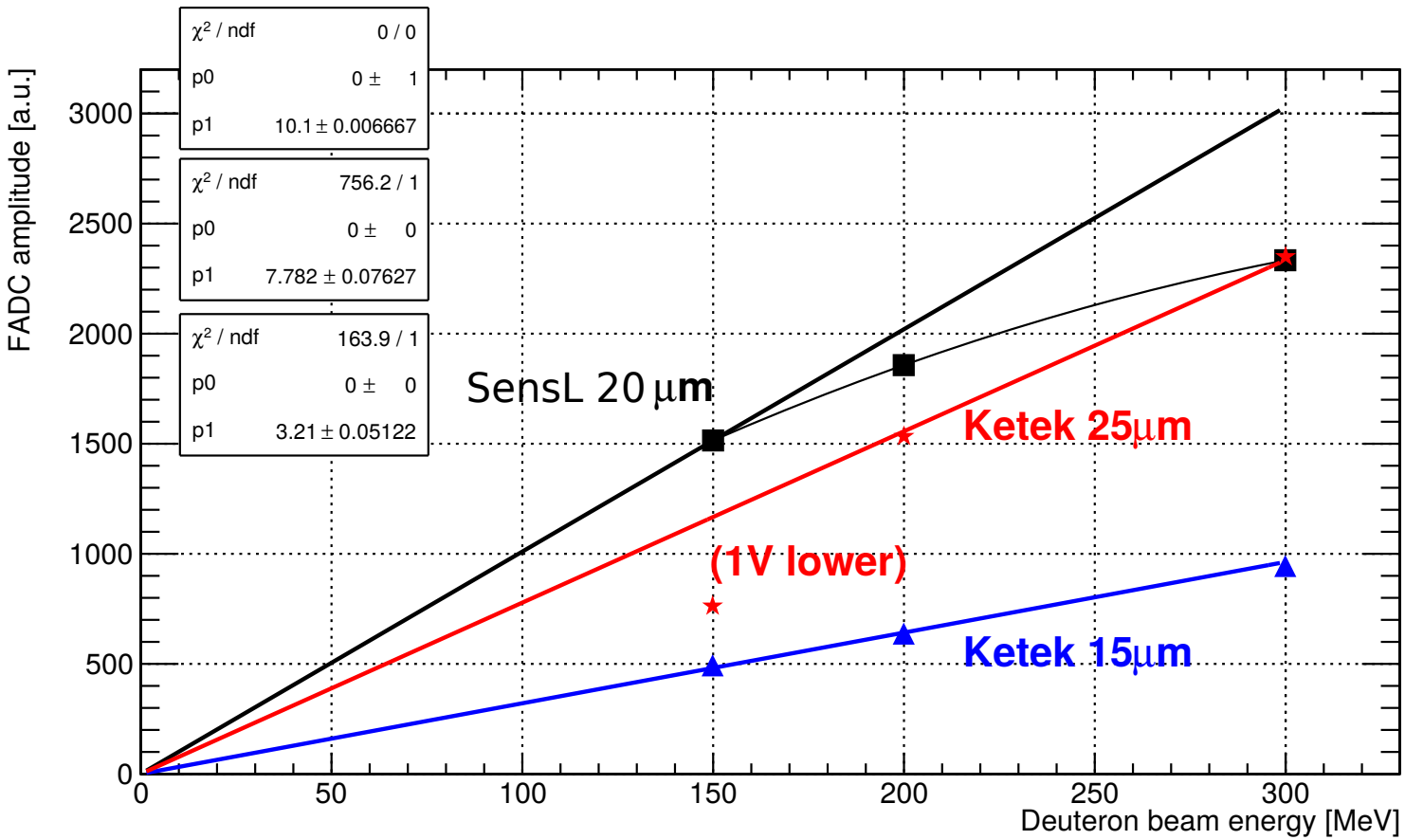
Note: big difference in gain!





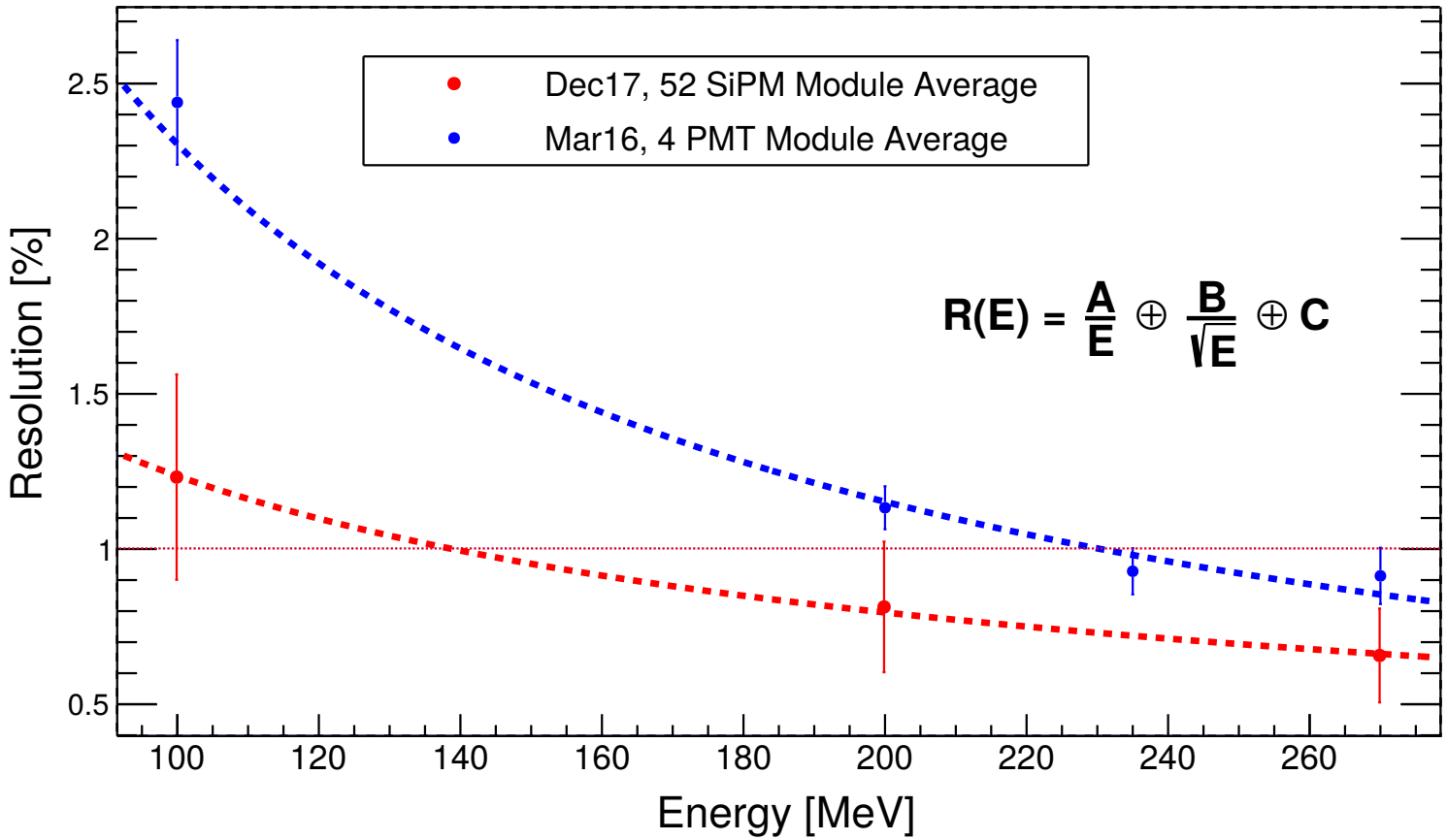
KETEK VS SENSL

Typical measured amplitudes for SensL 20 μm (*black*), Ketek 25 μm (*red*) and Ketek 15 μm (*blue*) pixel size array vs. deuteron beam energy. *All points are pedestal subtracted.*



KETEK VS SENSL

The comparison of energy resolutions as a function of incoming deuteron beam energy.
Blue: a very first measurement of the LYSO crystals with PMT readout.
Red: average of all modules with SiPM readout from December 2017 beam time.
Note: here the resolution is defined as a FWHM over all modules divided by amplitude.



A 2D scans of LYSO-SiPM modules

SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)

Next Generation LYSO:Ce,Ca Single Crystals

S. Blahuta [1*], V. Ouspenski [1], P. Menge [2], K. Yang [2]
* samuel.blahuta@saint-gobain.com
1.Saint-Gobain Recherche, AUBERVILLIERS, FRANCE
2.Saint-Gobain Crystals, HIRAM, OH, USA

2014 IEEE NSS
N27-53

Context

LYSO:Ce for Positron Emission Tomography (PET)

PET scanner ring — 2 photons 511 keV @ 180° — Crystals + Photomultiplier Tubes

	Density	1/μ (511 keV)	$\lambda_{emission}$ (nm)	Light Yield (ph/MeV)	Energy Resolution	Decay time
BGO	7.1	10.5 mm	480	8200	15%	300 ns
LuAP:Ce	8.3	10.6 mm	365	11000	9%	60 + 600 ns
LSO:Ce	7.4	11.5 mm	420	30000	9%	40 ns + afterglow
LYSO:Ce (10%Y)	7.1	12.2 mm	420	32000	8%	40 ns + afterglow

LYSO:Ce combines interesting features:
- High density
- Suitable $\lambda_{emission}$ for PMTs,
- Good scintillation performance

Grown by Czochralski technique

Possible improvements:
- Faster Decay Time
- Lower Afterglow

Czochralski growth

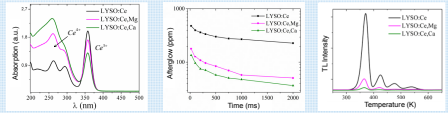
Consequences of co-doping

Crystal Composition	Pulse Height (^{137}Cs – 662 keV) Light Yield (photons / MeV)	Energy Resolution	XRL Rel. intensity
LYSO:Ce	28,000	8.9%	1
LYSO:Ce,Mg	33,000	8.4%	1.12
LYSO:Ce,Ca	34,000	8.5%	1.19

Performance improvement:
- Higher Light Output
- Reduced Afterglow

Ce⁴⁺ stabilization:
- Proved with XANES [1]
- Ce^{4+} has to be considered (WO 2012/066425)

Proposed explanation:
- Less efficient trapping due to Oxygen vacancies stabilization
- Charge compensation mechanism with Ce^{4+}



Limits of standard co-doping

Uncontrolled co-doping content:
- Bad crystal growth leading to spiral shape
- Cracks more likely to occur

Possible explanation:
- Reduced surface tension due to too many impurities (Ca, Mg…)

Spurrier et al. J. Crystal Growth (2008) 310 [2]

Performance enhancement by increasing co-doping content is limited.
→ A compromise is required

Solutions and Improvements (3rd Generation LYSO)

Optimized composition

Optimized doping and co-doping contents
Oxidizing agent (e.g. MO_2) can be used during the growth:
- Decomposition in the melted bath
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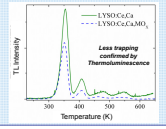
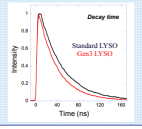
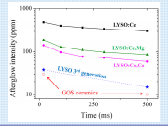
Performance improvement

Composition	Standard LYSO	LYSO:Ce,Ca	Gen3 LYSO
Light Yield (Photons/MeV)	28,000	34,000	38 – 42,000
Decay time	43 – 45 ns	42 ns	34 – 37 ns
Energy Resolution	8.9%	8.5%	7 – 8%
Afterglow	High	Medium	~ GOS ceramics







Controlled Growth

Progressive optimization of the composition:
- Improved crystal growth
- High quality material with enhanced performance

Conclusions & Perspectives

Improvements and Limitations with standard co-doping:
- Improved Light Yield, Decay Time and Afterglow
- Stabilization of Ce^{4+} for charge compensation
- Uncontrolled co-doping leads to bad crystal growth
- ✧ A Growth/Performance compromise is required

The oxidizing agent technique
- Solution to growth issues with high co-doping
- Source of oxygen during the growth
- No significant pollution to impact scintillation
- ✧ NEW possibilities for scintillator preparation

3rd GENERATION LYSO
- Light Yield better than 40000 Ph/ MeV (γ 662 keV) ;
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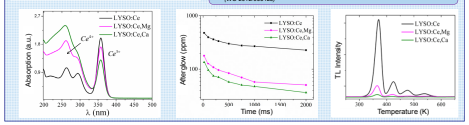

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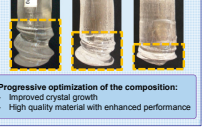

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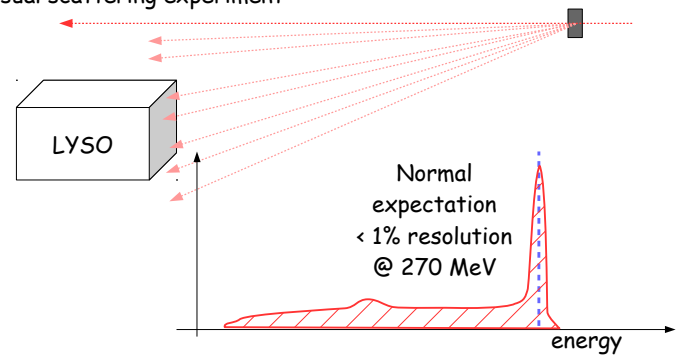
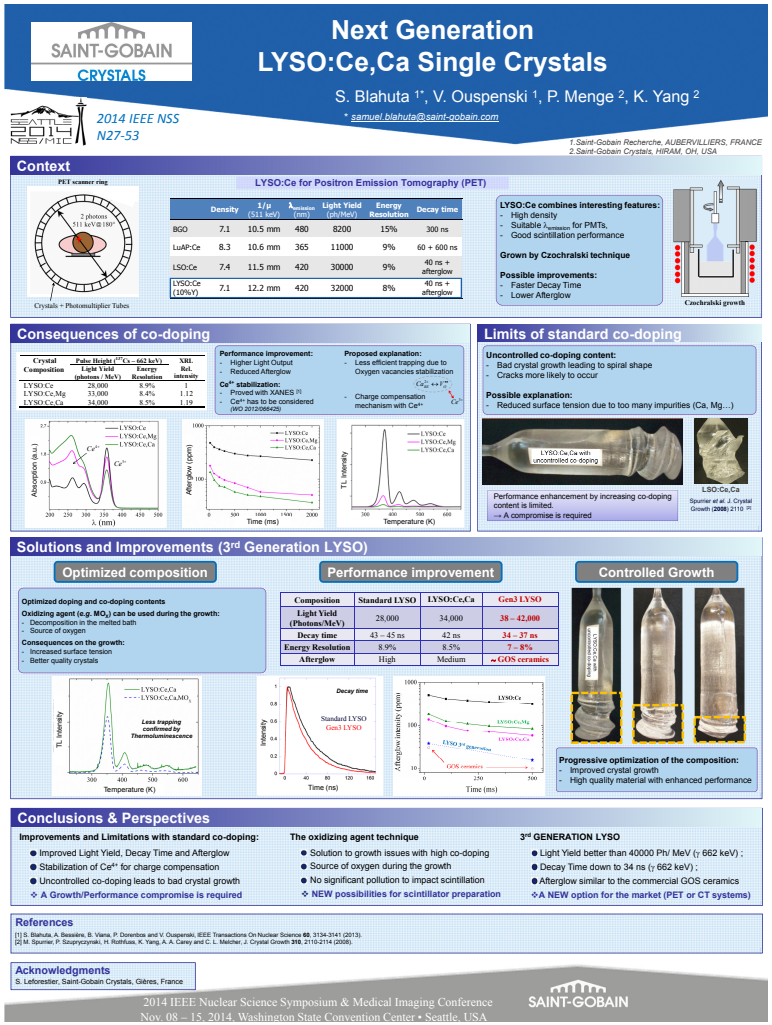
SAINT-GOBAIN

a) Usual scattering experiment



SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)



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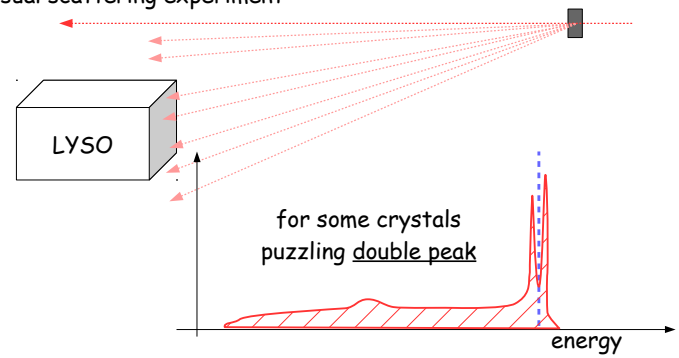
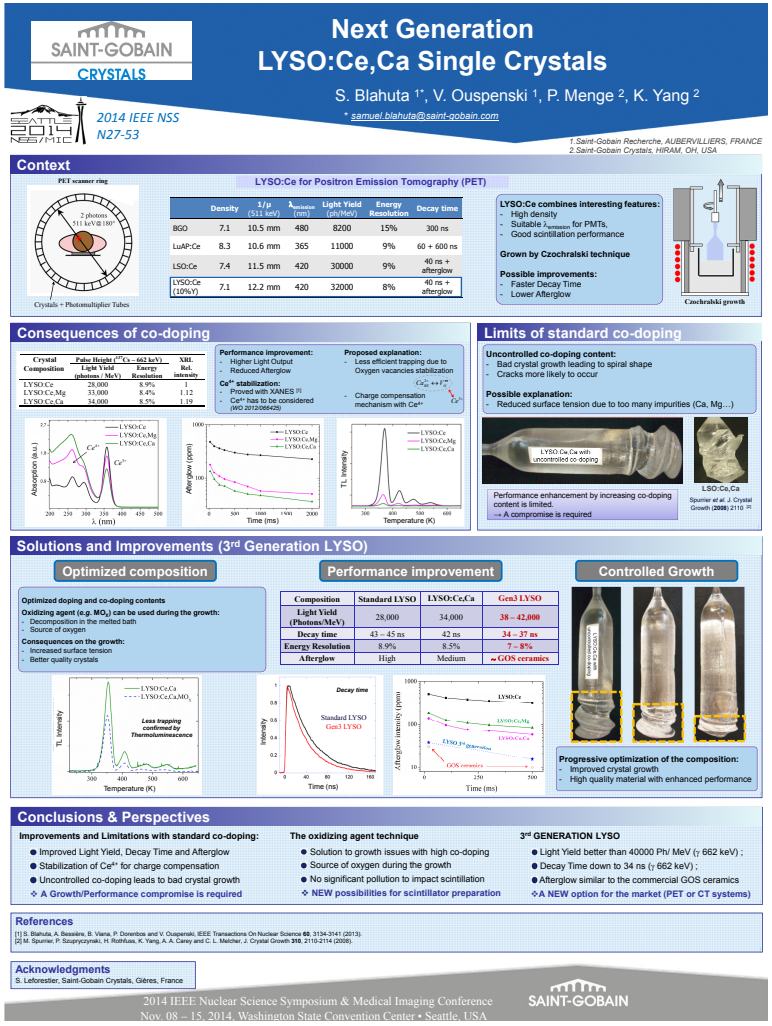


It was actually appearing
almost randomly…
The same crystal time to time had
absolutely **clean signal**
but in some situations manifesting
double peak!

SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)



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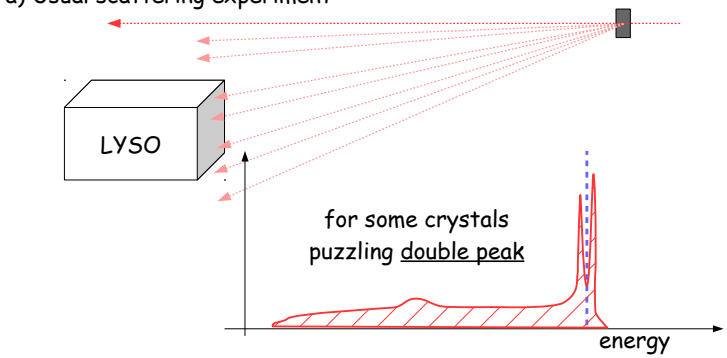
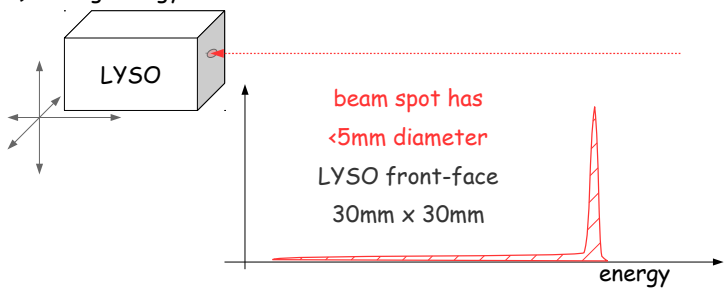


b) During energy calibration



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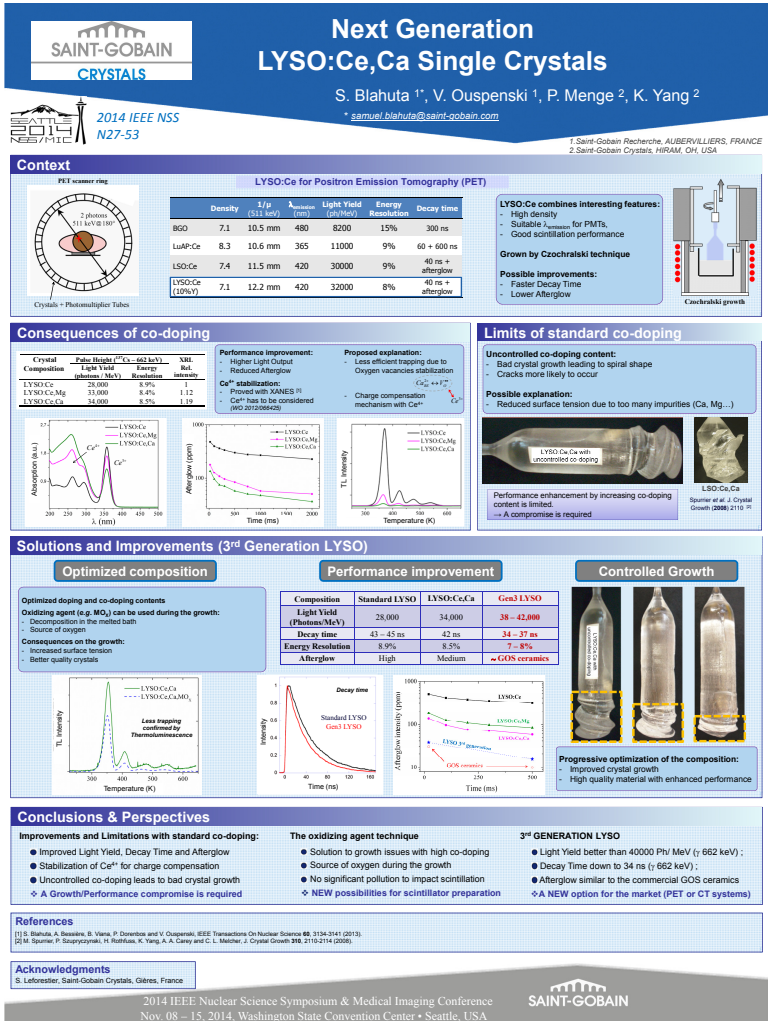
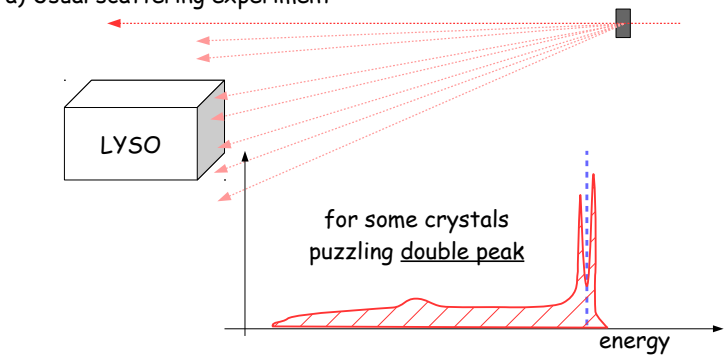
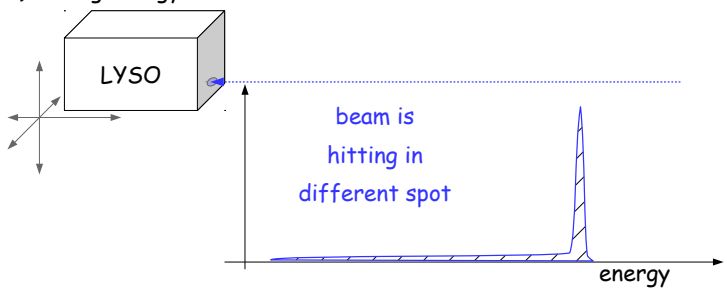


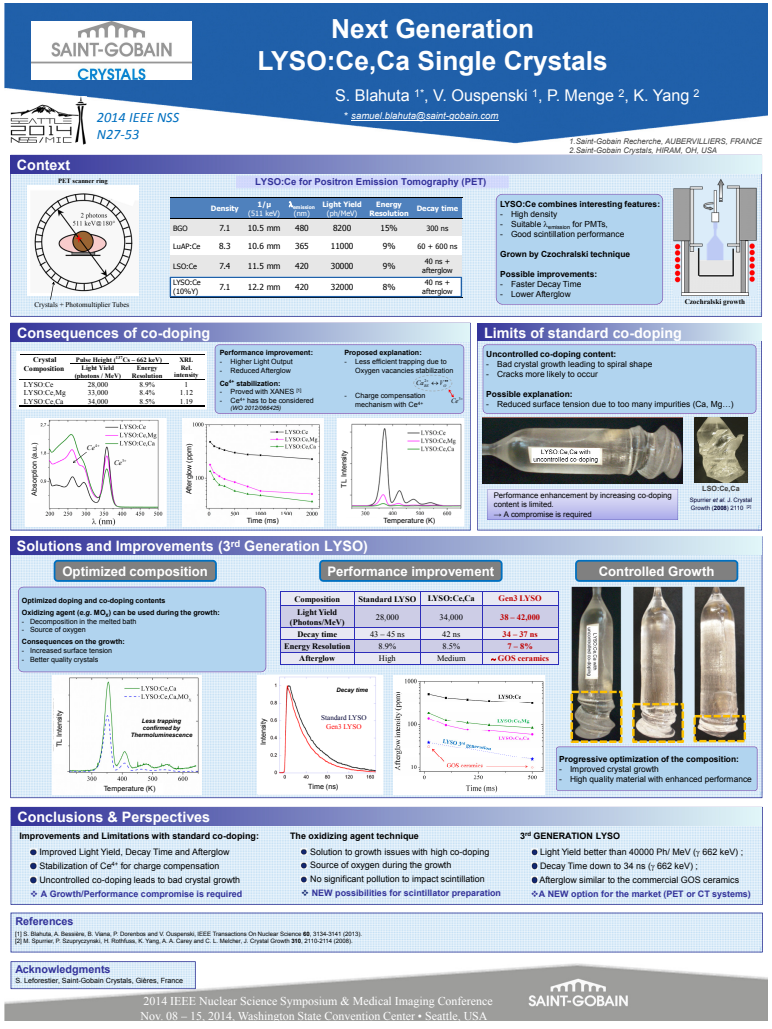
a) Usual scattering experiment



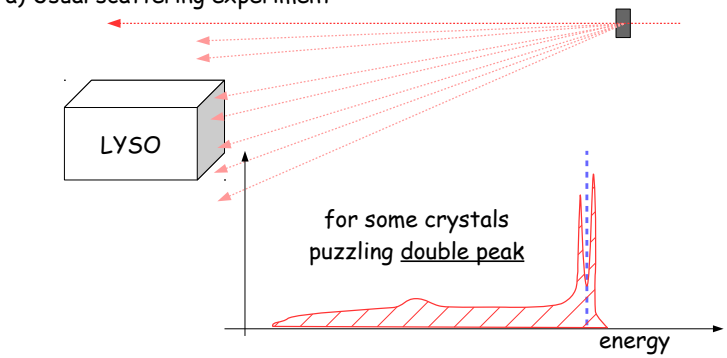
b) During energy calibration



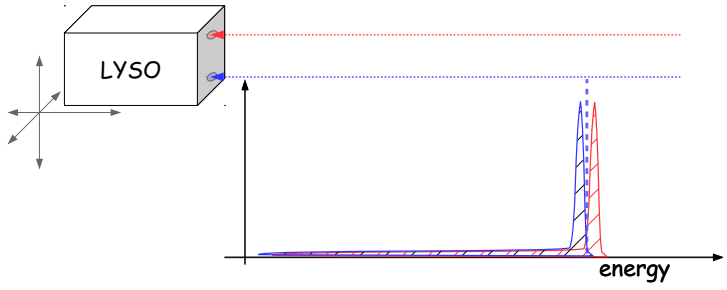
SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)



a) Usual scattering experiment

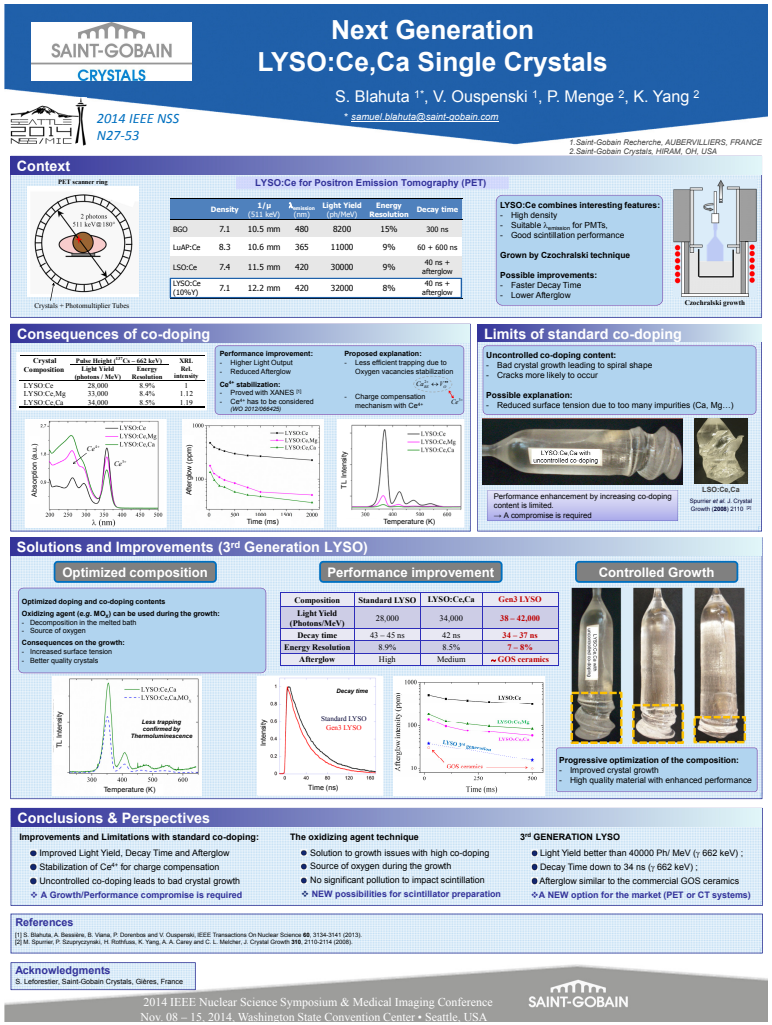


b) During energy calibration

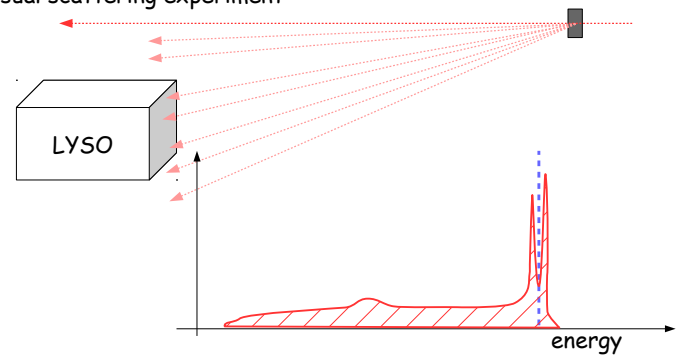


Peak is front face
position dependent!
Is it also energy dependent?
not really…

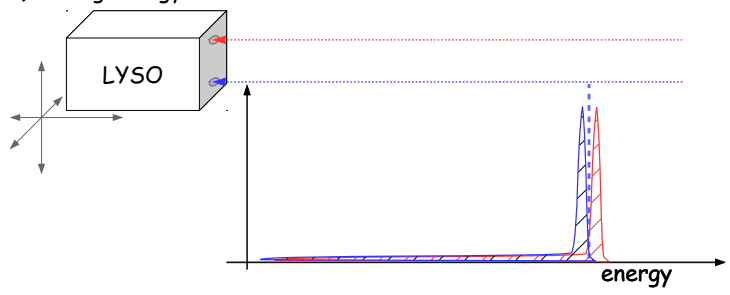
SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)



a) Usual scattering experiment



b) During energy calibration

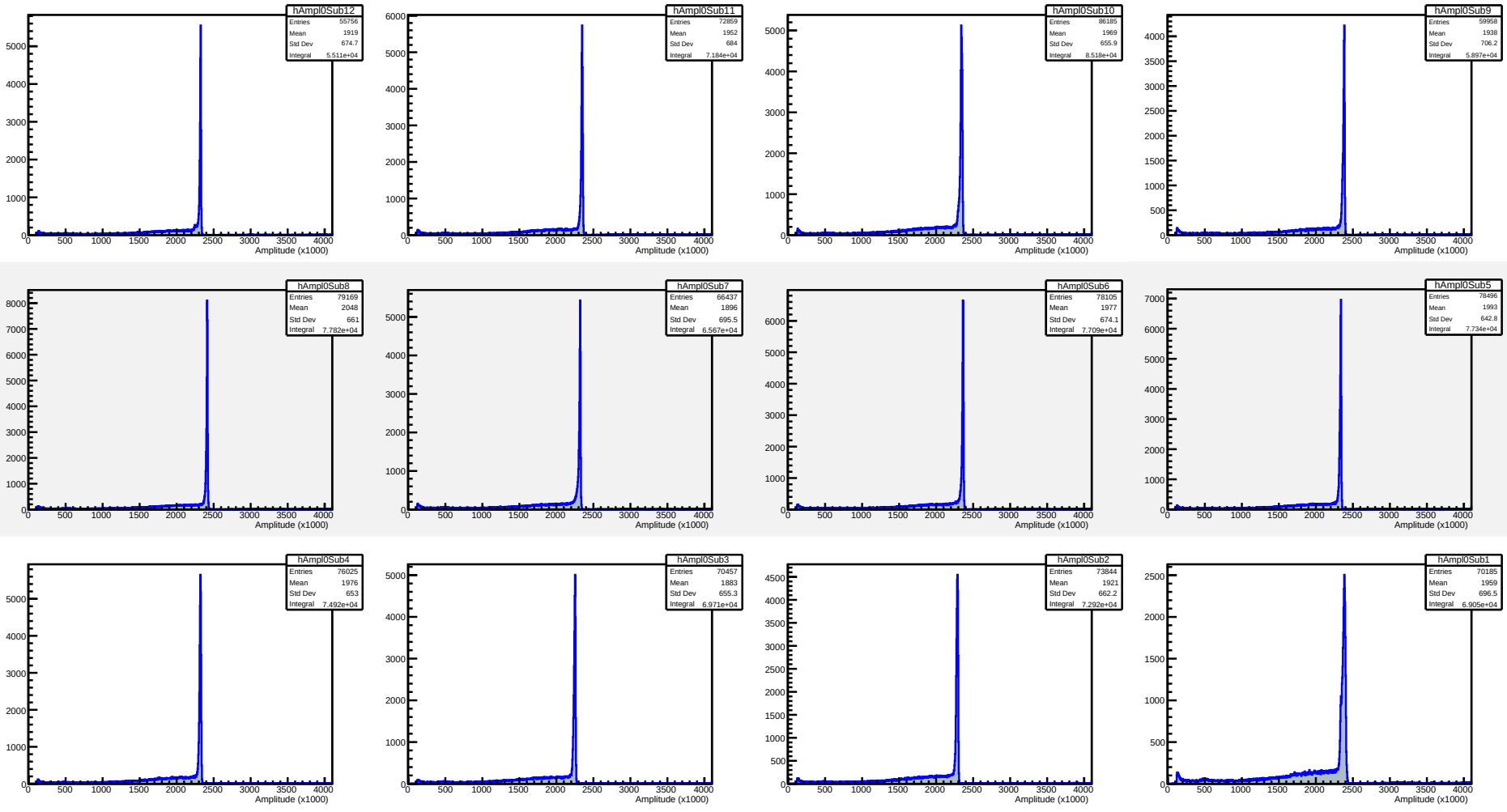


c) Different hypotheses

We spend <3 days of March beam time
to clarify this problem
very successfully !
We measured 2D maps for all crystals at
150, 200, 300 MeV

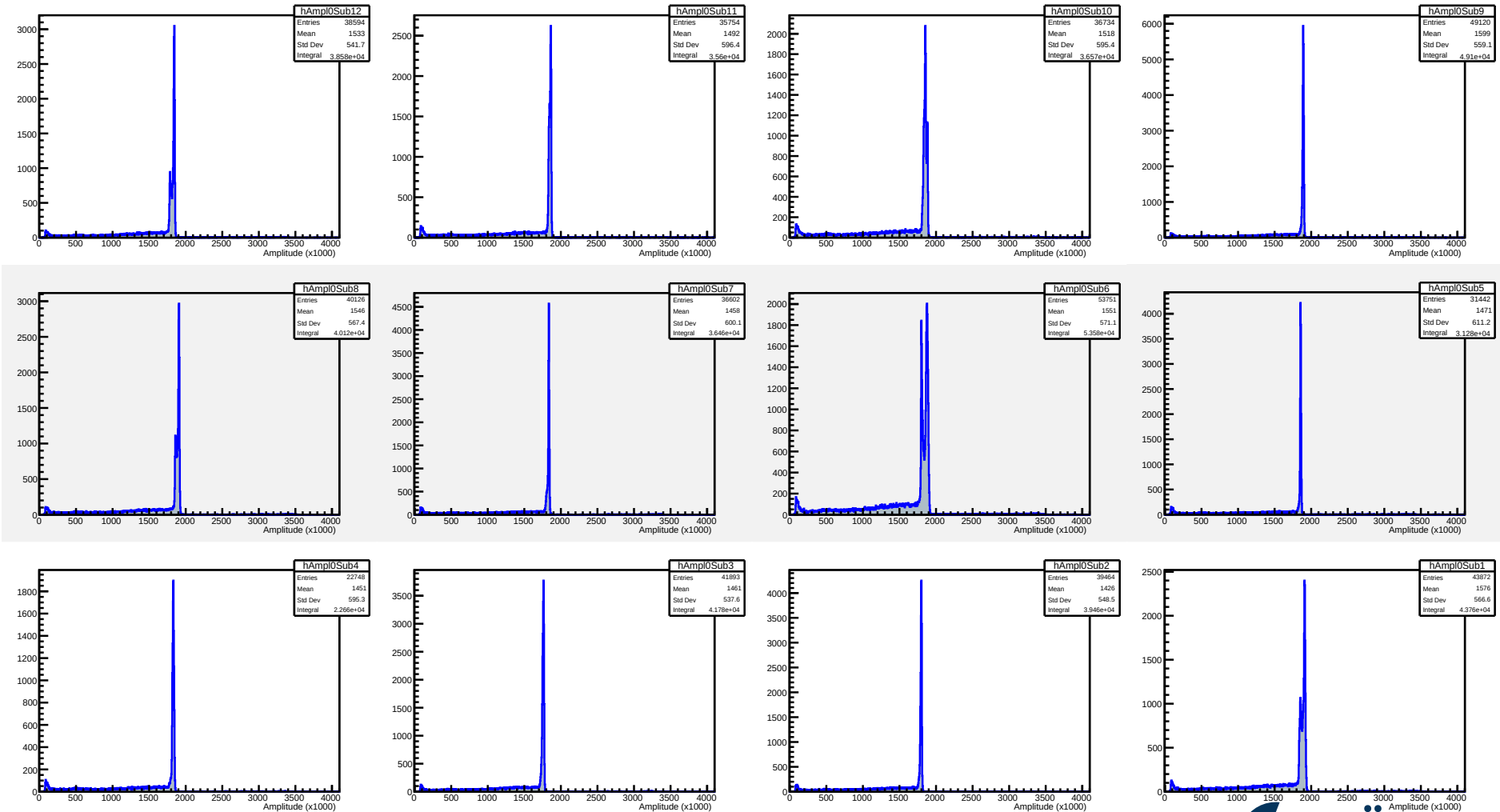
TYPICAL PICTURE — LEFT ARM OF THE POLARIMETER

Beam energy 300 MeV



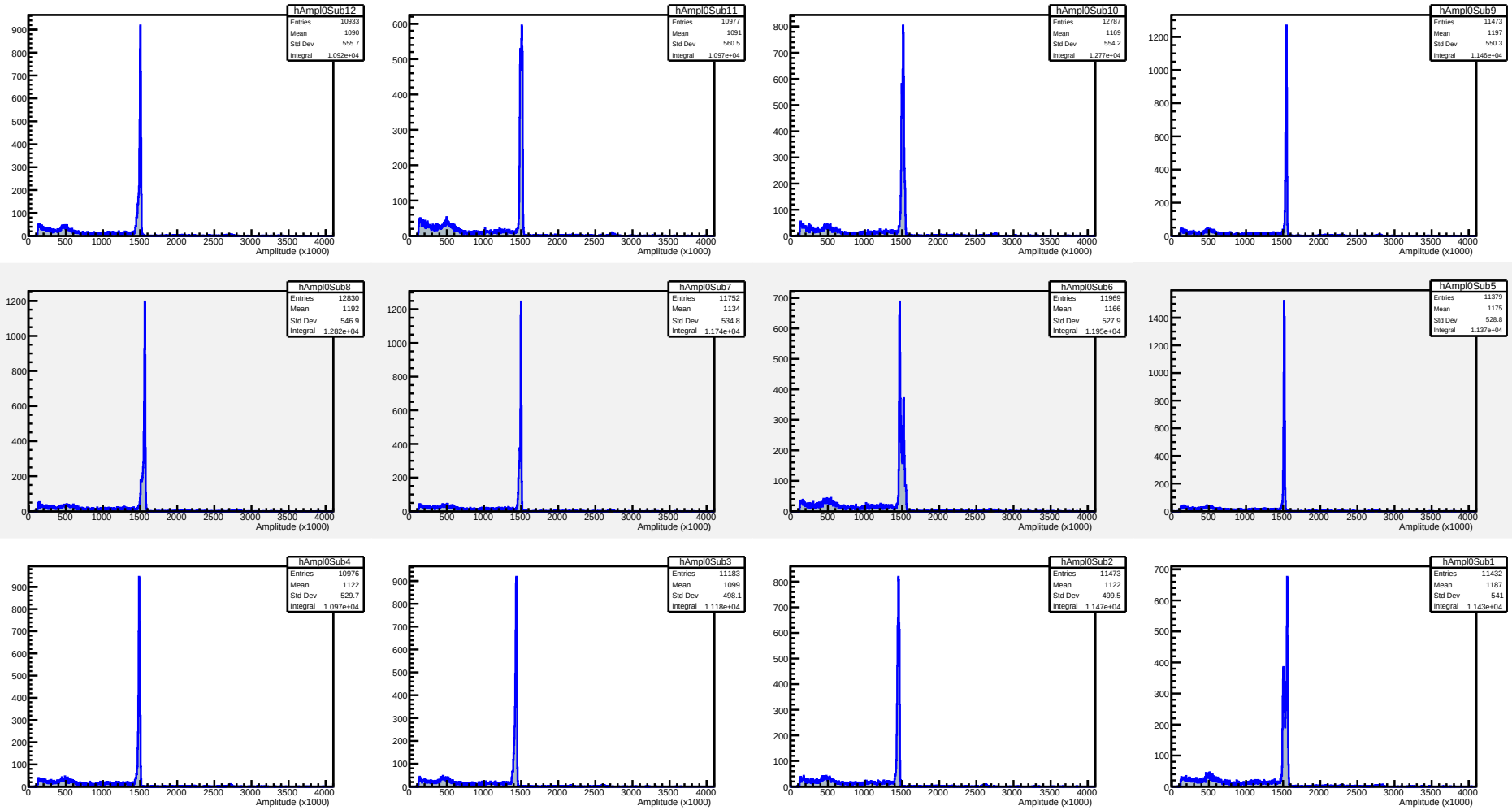
TYPICAL PICTURE — LEFT ARM OF THE POLARIMETER

Beam energy 200 MeV



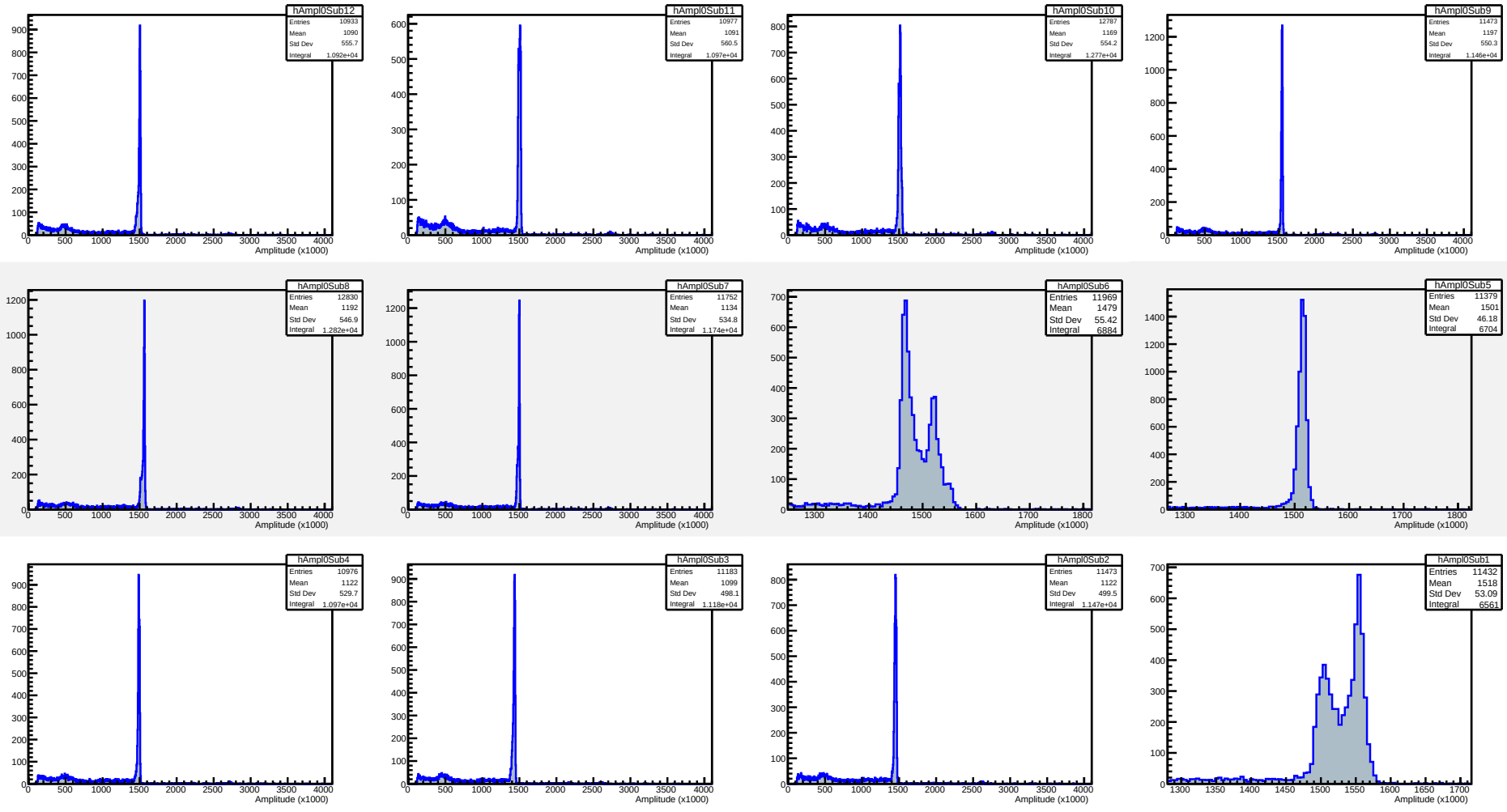
TYPICAL PICTURE — LEFT ARM OF THE POLARIMETER

Beam energy 150 MeV

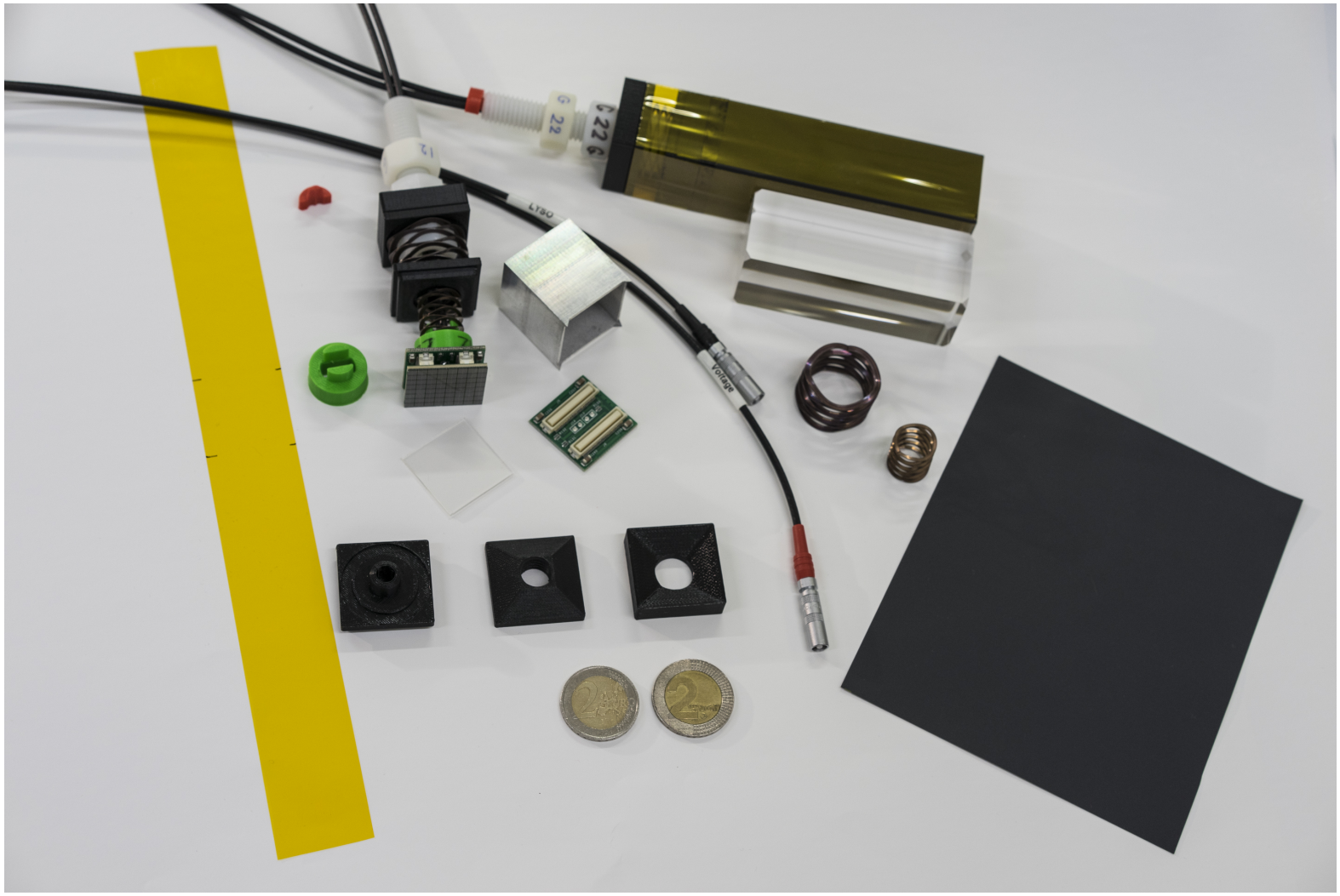


TYPICAL PICTURE — LEFT ARM OF THE POLARIMETER

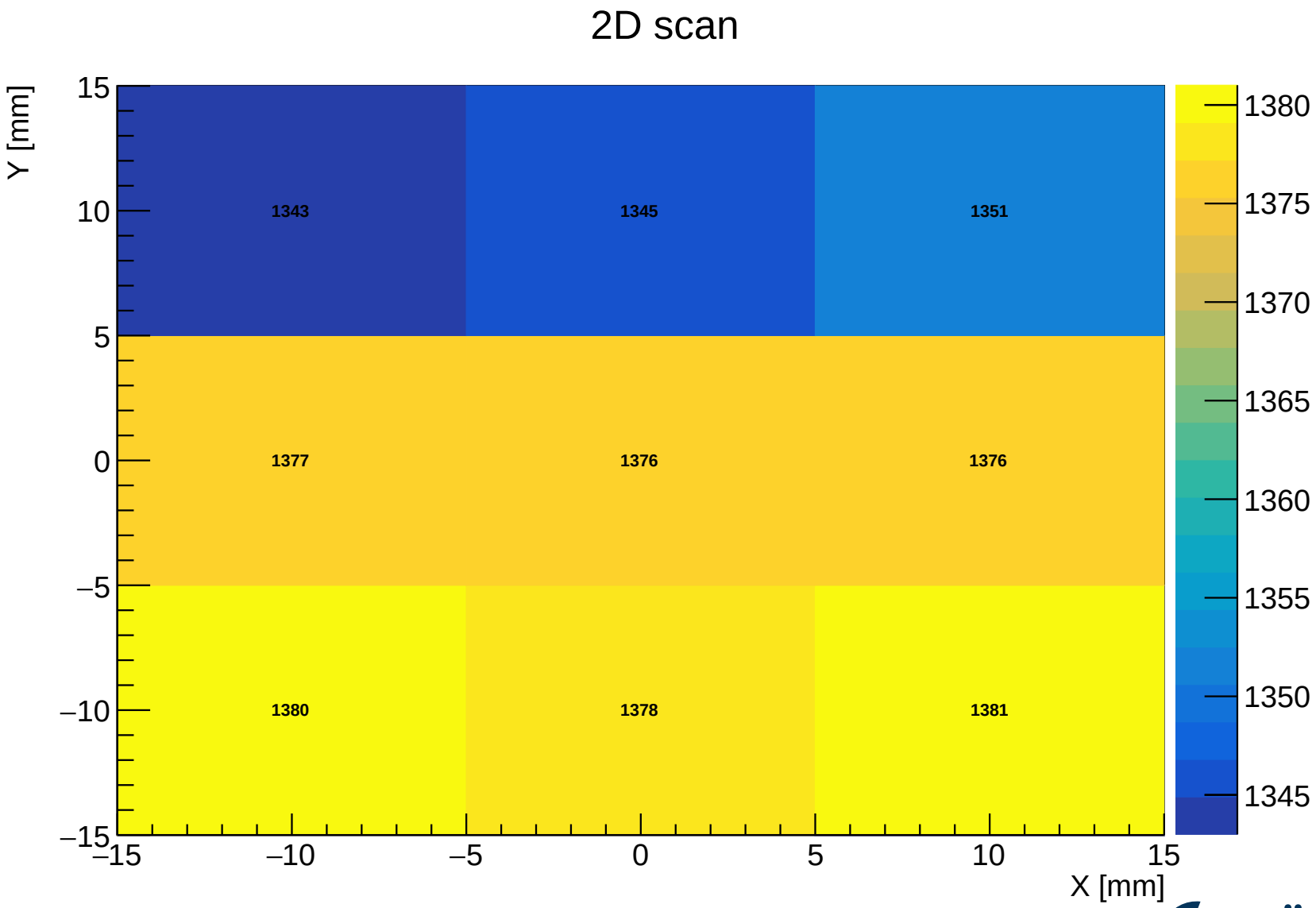
Beam energy 150 MeV – zoom



LYSO MODULE

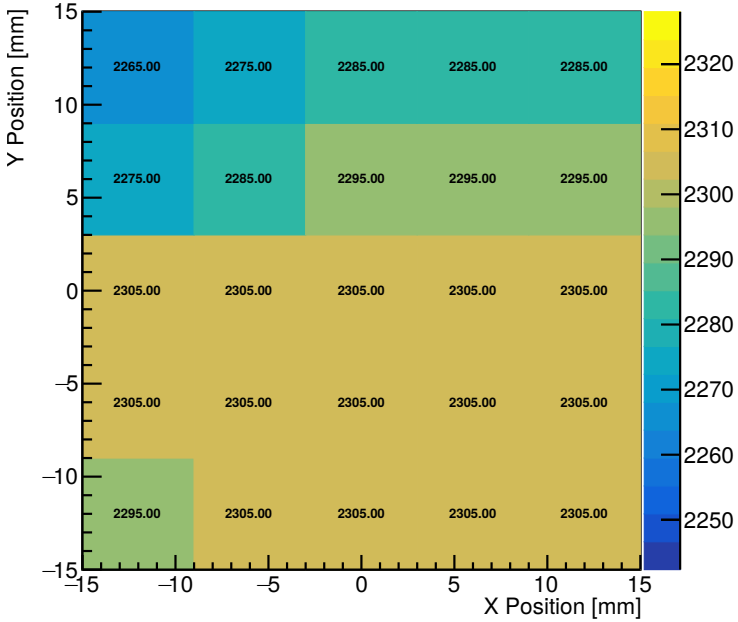


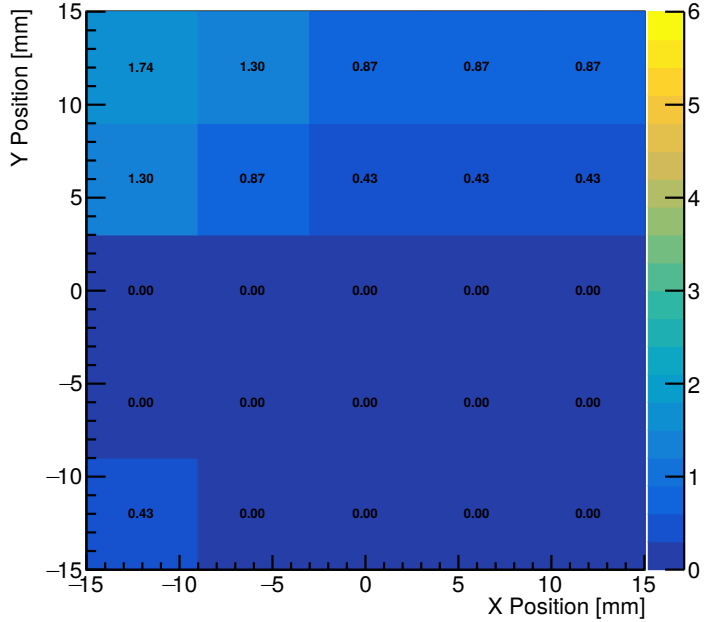
LYSO MODULE SCAN



2D FRONT-FACE MODULE RESPONSE MAP

A 5×5 front face map of a LYSO crystal with a $300 MeV$ deuteron beam.



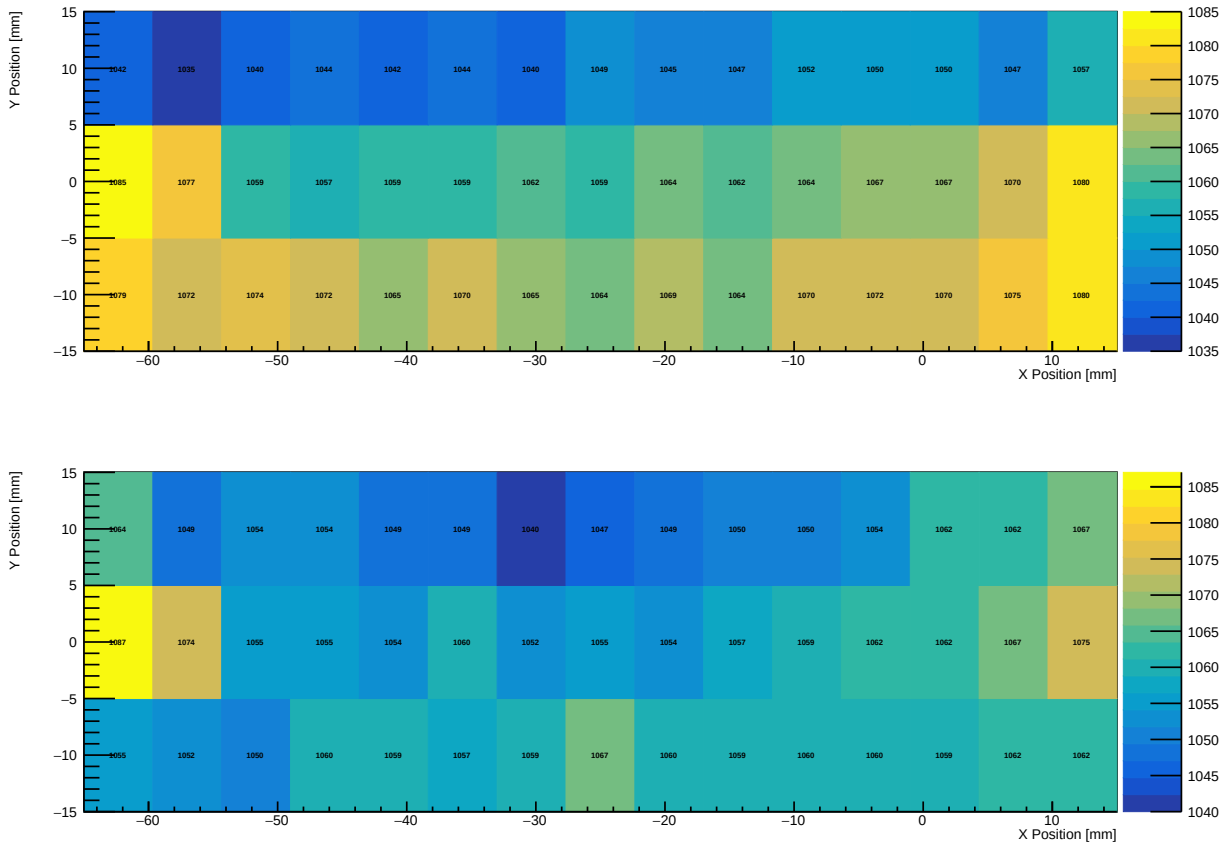


The absolute values of peak position of the beam energy.

The relative deviation from the maximum value showing the homogeneity of the energy reconstruction to be $< 1.8\%$.

CRYSTAL SIDE SCAN

A 15×3 side face map of a LYSO crystal at $300 MeV$ deuteron beam. In both measurements, the sensor is located on the right side. Upper: The same orientation as from slide 17. Evident lowering of the light output can be identified in the upper part of the crystal. Lower: The 90° rotated map of the same crystal showing a different light output distribution from the upper face.

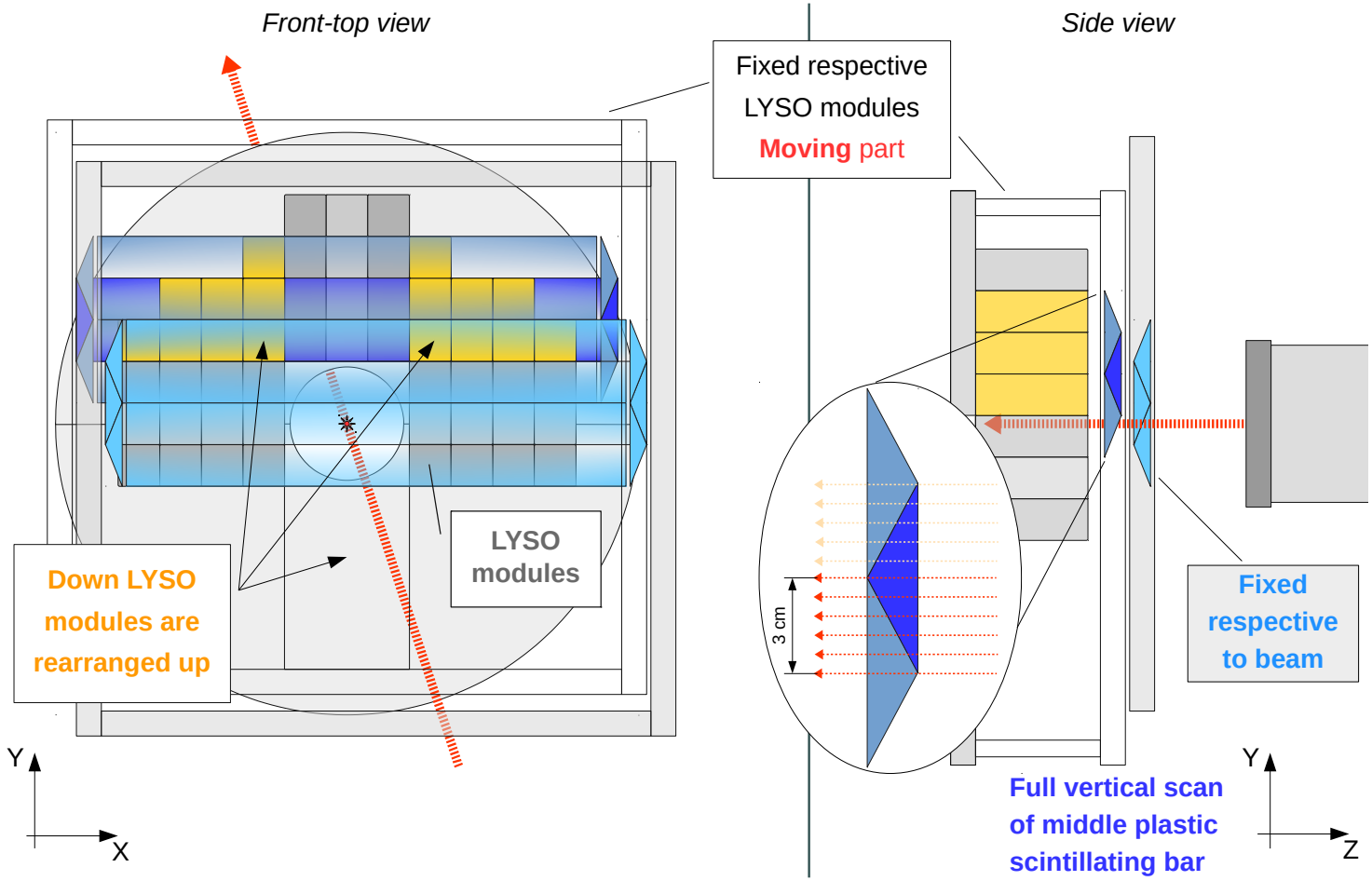


The plastic scintillator tracker

PLASTIC SCINTILLATOR TRACKER

Consisting of the overlapping triangular scintillator bars. The upstream (forward) frame is installed to be fixed vertically relative to the beam while the downstream (backward) frame can scan the beam.

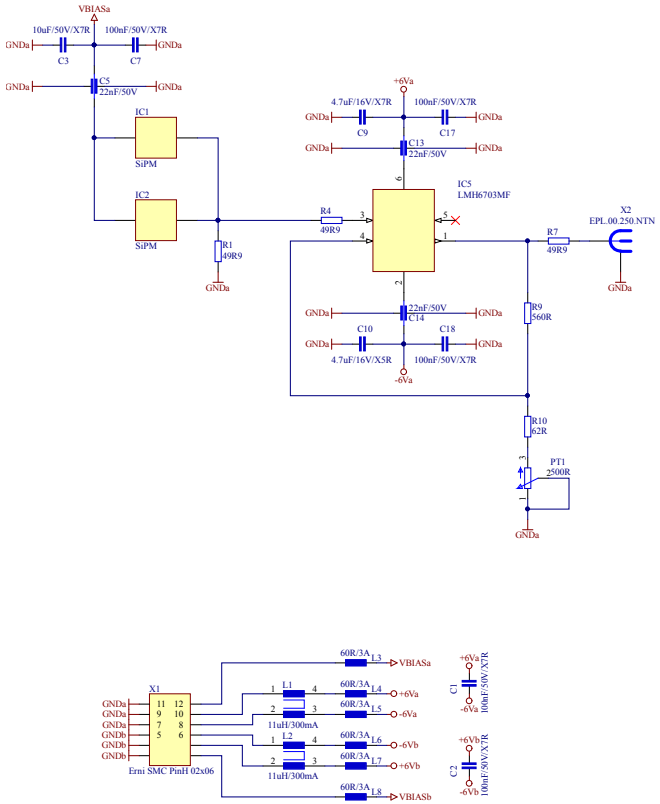
All scintillators were scanned vertically and horizontally (along the bar).

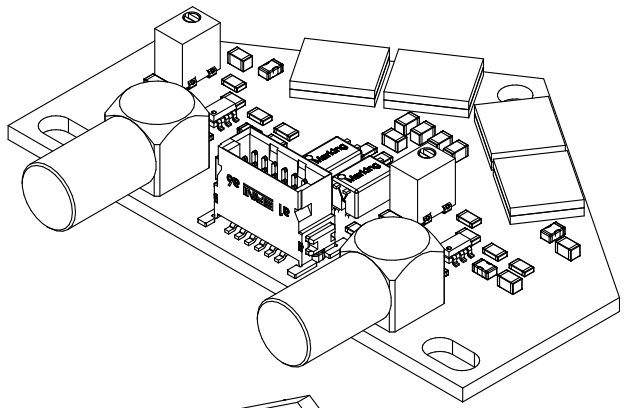


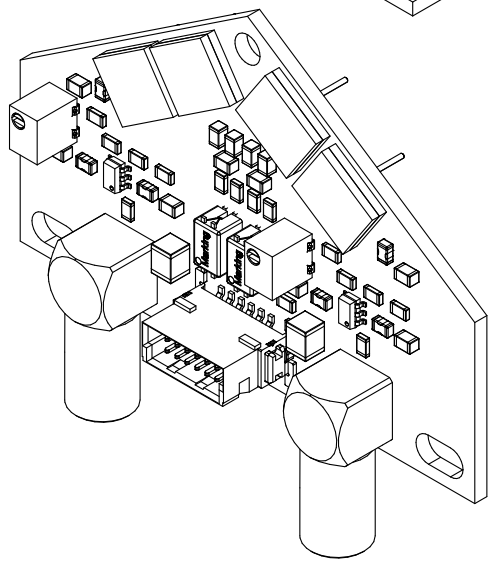
PLASTIC SCINTILLATOR TRACKER READOUT PCB

Dual channel operational amplifier based SiPM signal preamplifier PCB

The supply voltage $\pm 6\,V$ and reverse bias voltages $+29\,V$ is shared for each PCB







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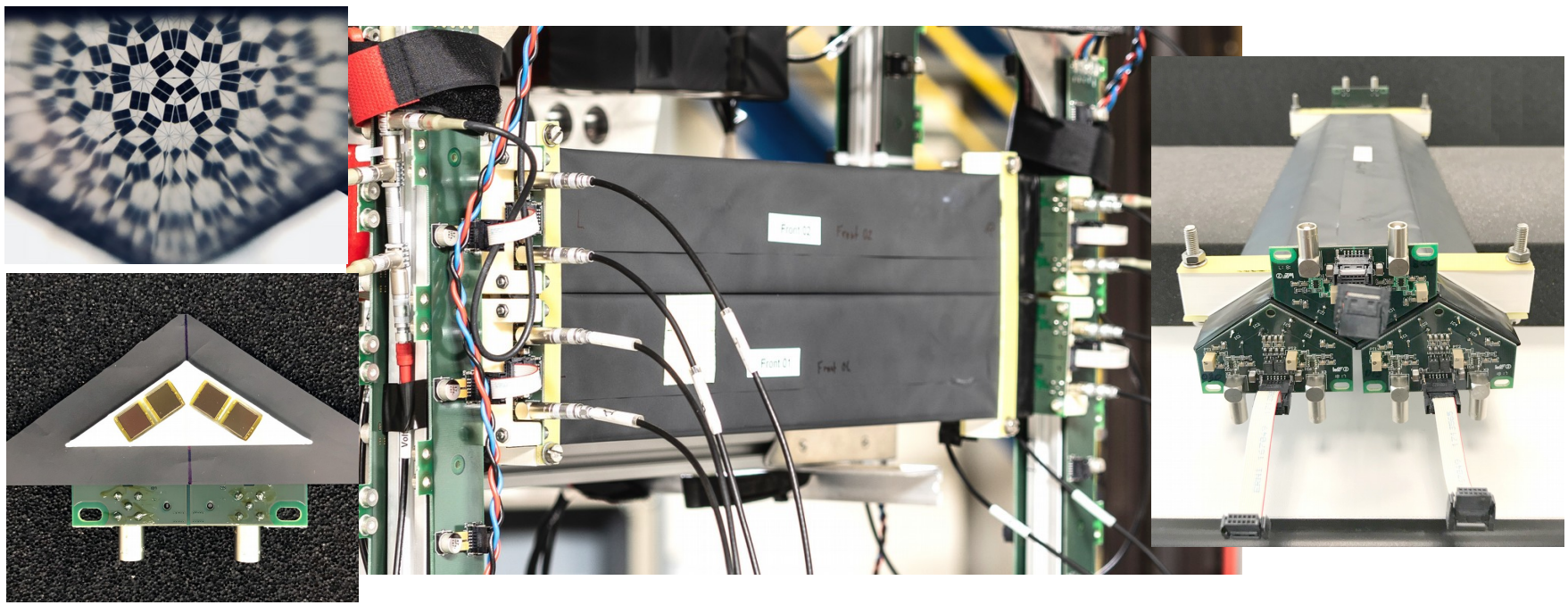
PLASTIC SCINTILLATOR TRACKER

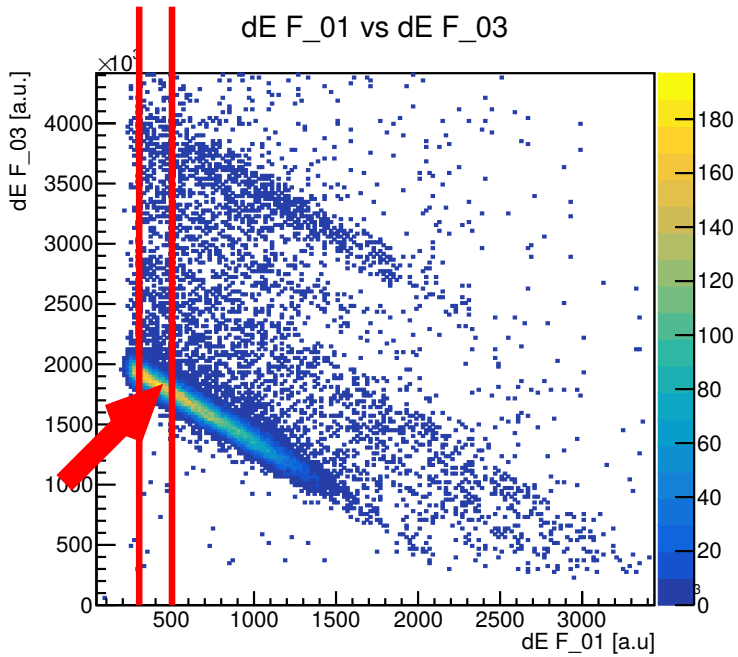
Left-up: the view through the wrapped triangular scintillator bar where the kaleidoscopic picture of the SiPM's is seen from another end.
Left-down: the end cup of the bar is shown with four SiPM's split into two independent preamplifier channels.
Middle: already attached tracker in front of LYSO modules.
Right: one of the layers with three bars after assembly.

Each counter has 4 independent preamplifier output, 2 each end, and eight 6×6 *mm* SiPM's four each end.

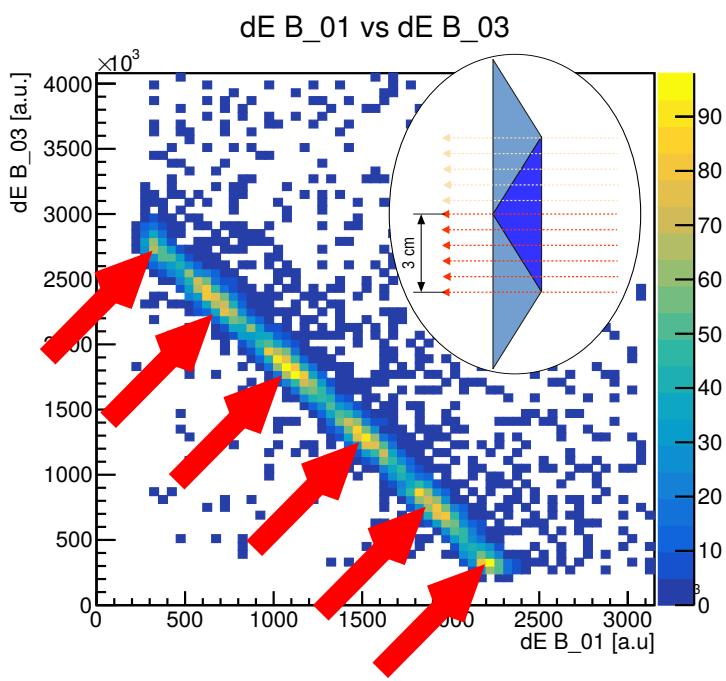


PLASTIC SCINTILLATOR TRACKER

The amplitude correlation histograms for the forward and backward layers of two overlapping triangular scintillator bars. The apparent correlation between the amplitudes is demonstrated.



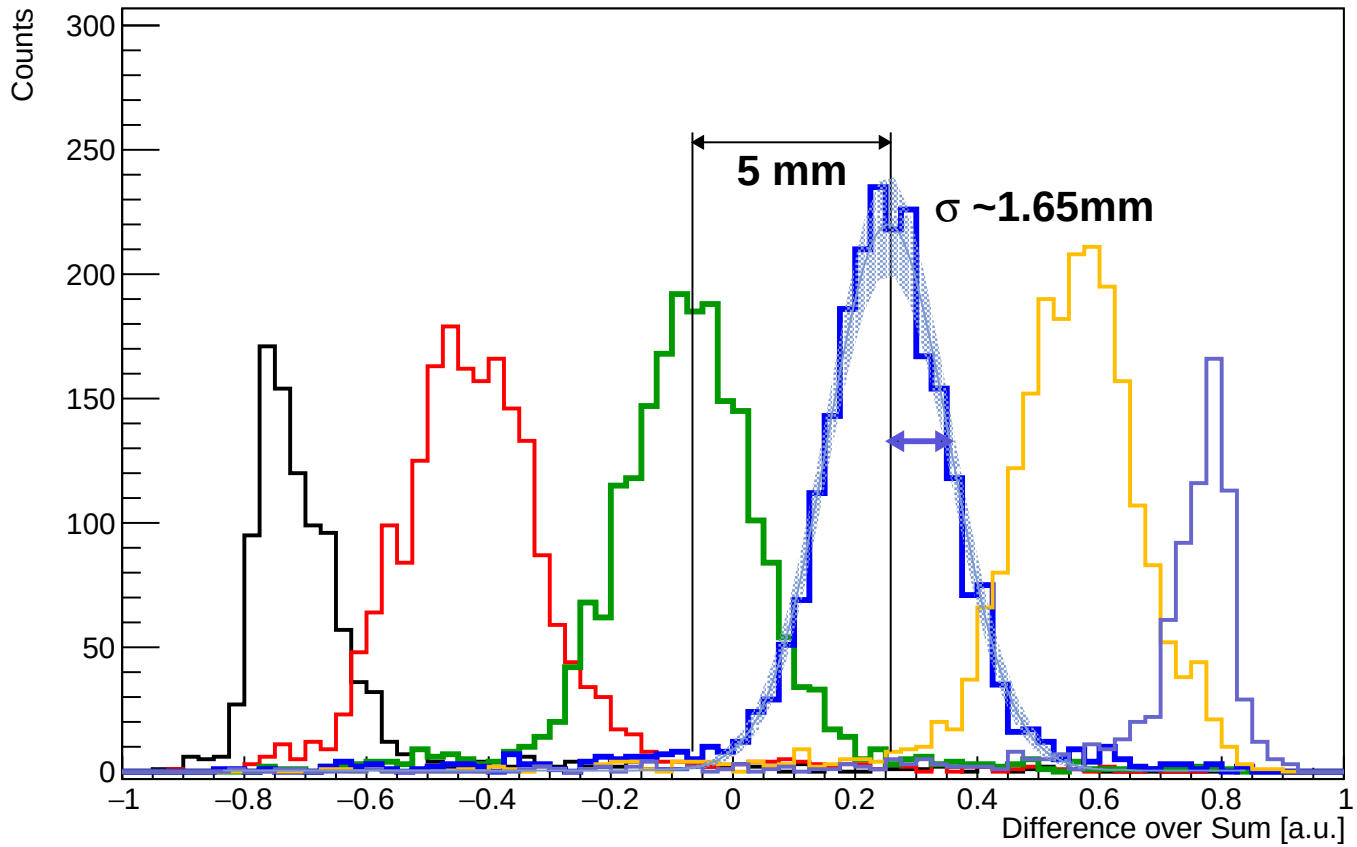
a forward layer which is fixed relative to the beam and showing only the beam spread. The red lines show the cut area to choose a relatively focused beam for the second layer.



the correlation in the second layer while scanning along the overlapped side.

RESOLUTION PLASTIC SCINTILLATOR TRACKER

The difference over sum ($\frac{A_1 - A_2}{A_1 + A_2}$) between the bars for six different positions along the overlapping sides (5 *mm* steps over a 3 *cm* side) of a backward layer is shown. Without much effort, the few millimeter resolutions can be achieved.



The EPICS based system for the

- parameter monitoring (temperature, voltages, position, ...)
- archiving for the easy access of full history
- COSY compatible EPICS CS-Studio slow control system

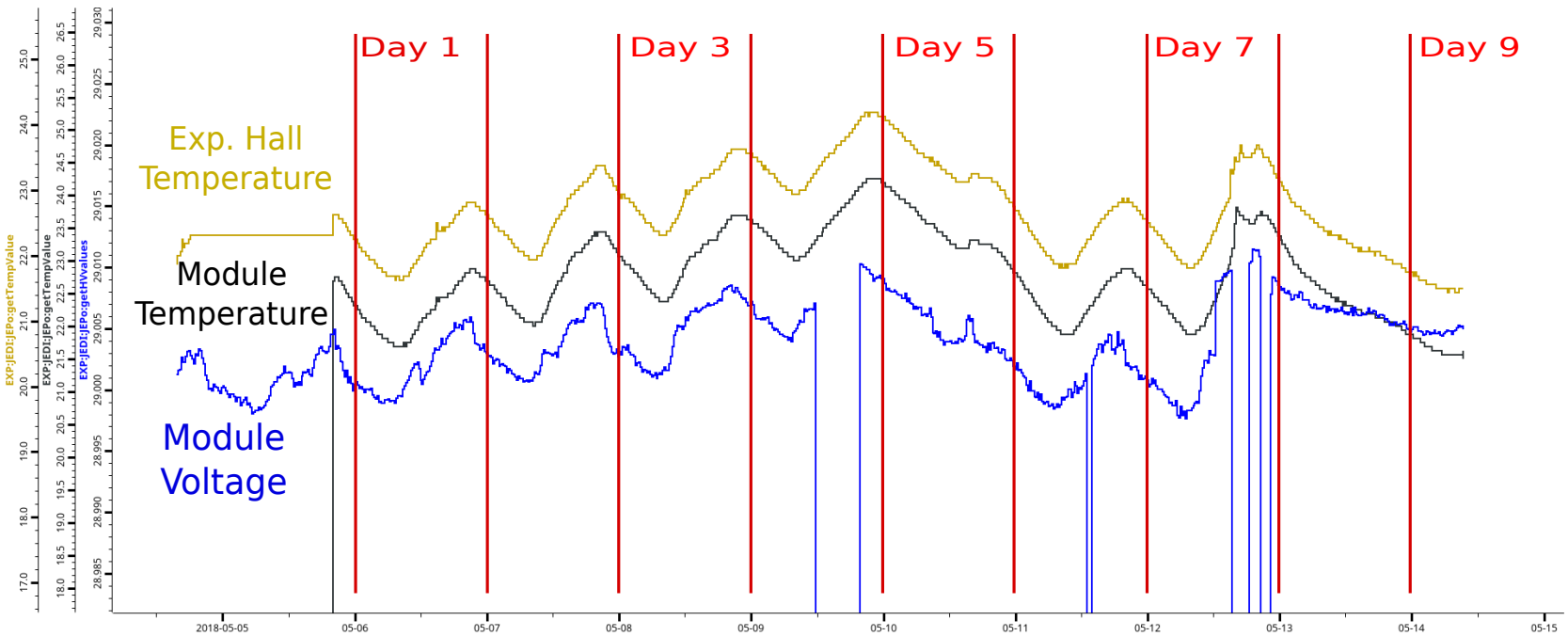
TEMPERATURE MONITORING AND ARCHIVING SYSTEM

The module internal (black) and

Big Karl exp. hall (brown) temperature variation vs. time over the whole beam time.

With the blue graph, the supply voltage for the same module is shown.

The apparent correlation between all the values is evident.



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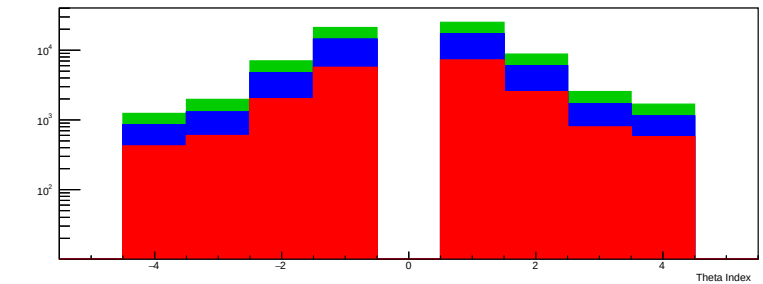
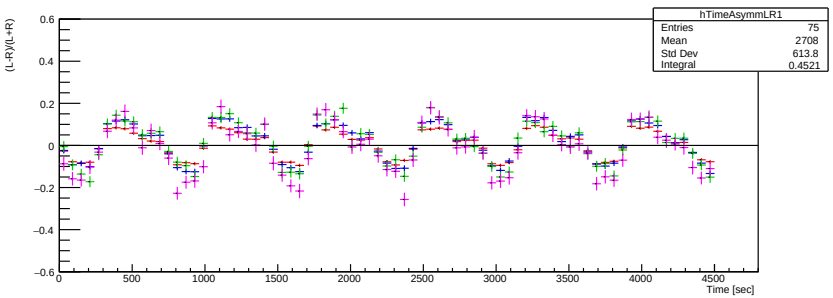
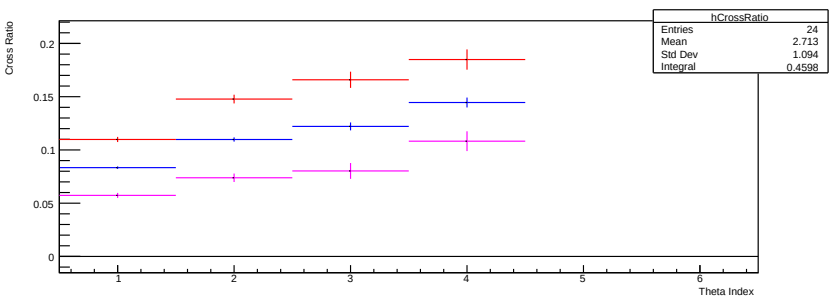
ONLINE ASYMMETRY FOR DIFFERENT TARGET MATERIALS

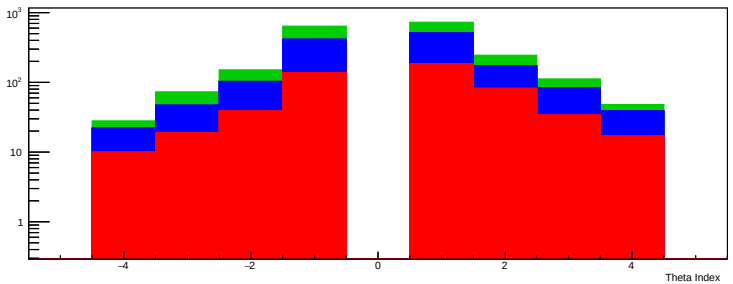
300 MeV Nickel

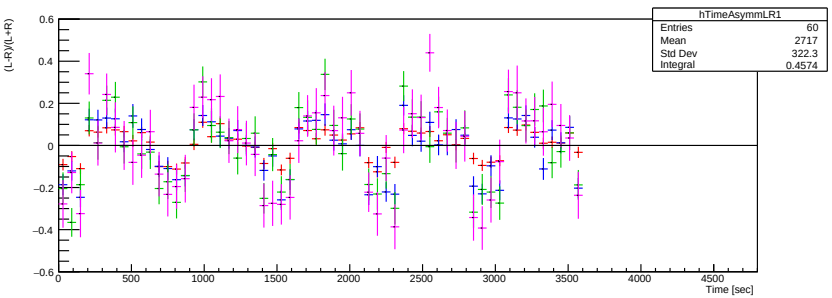


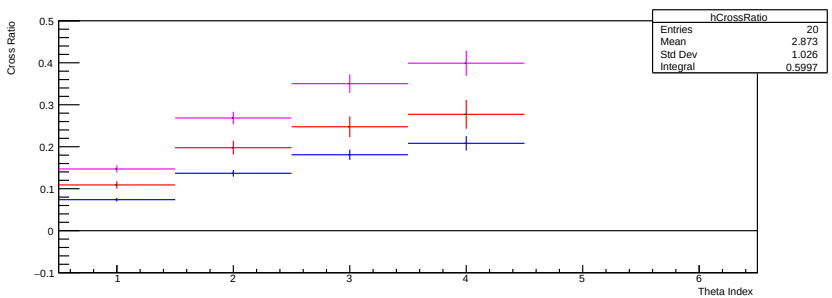




Tin







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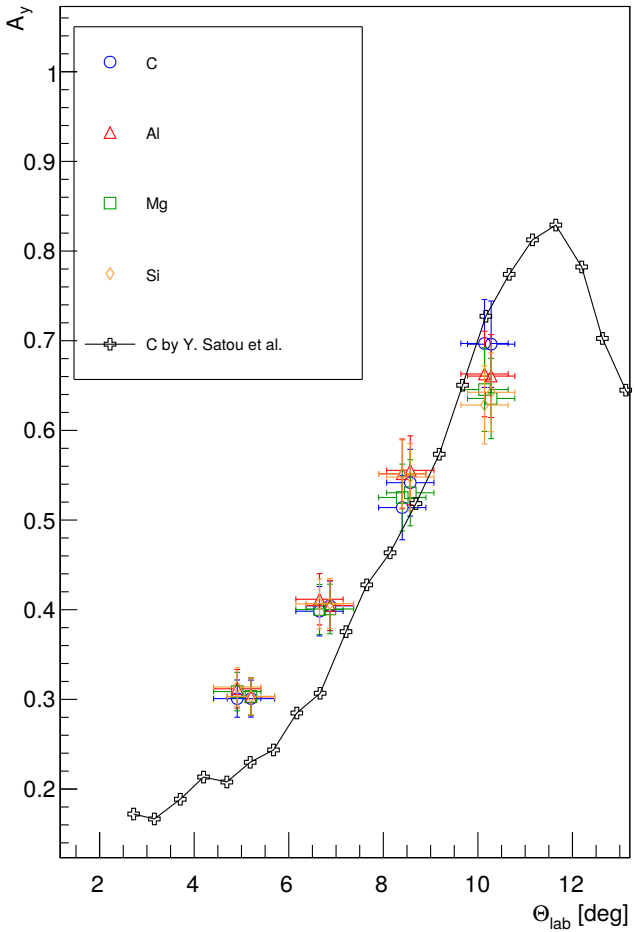
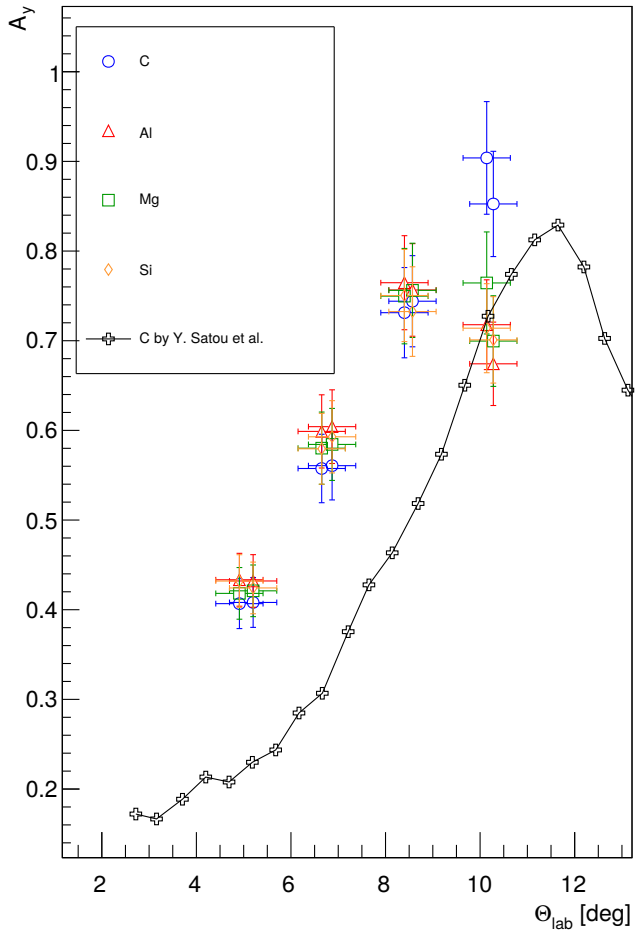
VECTOR ANALYZING POWER AT 270 AND 300 MEV





BEAM TIME REQUEST

- Extracted beam (BIG KARL)
- Polarized deuterons
- Energies of T_d =

  100, **200**, **270**, **300** *MeV*
- Low count rate ~ 1 ÷ 50 *kHz*
- 2 Week End of 2018

  (pure measurement time)

COSY Beam Time Request

For Lab. use	
Exp. No.: **E2.6**	Session No. **8**

Collaboration JEDI

Towards the EDM Polarimetry

Spokespersons for the beam time: **Irakli Keshelashvili (Jülich)**, **Bernd Lorentz (Jülich)**, **David Mchedlishvili (HEPI TSU)**

Spokespersons for the collaboration: **Jörg Pretz (Jülich)**, **Paolo Lenisa (Ferrara)**

Address:
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Forschungszentrum Jülich
52428 Jülich
Germany

Phone: **+49 2461 615603** Fax: **+49 2461 613930** E-mail: **j.pretz@fz-juelich.de**, **lenisa@fe.infn.it**, **i.keshelashvili@fz-juelich.de**, **b.lorentz@fz-juelich.de**, **d.mchedlishvili@fz-juelich.de**

Total number of particles and type of beam (p,d,polarization)	Kinetic energy (MeV)	Intensity or internal reaction rate (particles per second)	
		minimum needed	maximum useful
Extracted beam of polarized deuterons	**100, 200, 270, 300 MeV**	**10^3**	**10^7**
Experimental area	Safety aspects (if any)	Earliest date of installation	Total beam time (No.of shifts)
LYSO crystals at external BIG KARL area	**none**	**1st November 2018**	**2 weeks (+ MD)**

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Appendix

CONTACT

Contacting me via e-mail

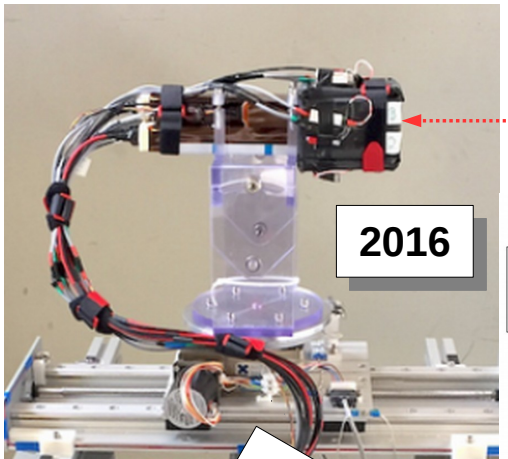
Click here: i.keshelashvili@fz-juelich.de

ACKNOWLEDGMENT

People contributing to the experiment

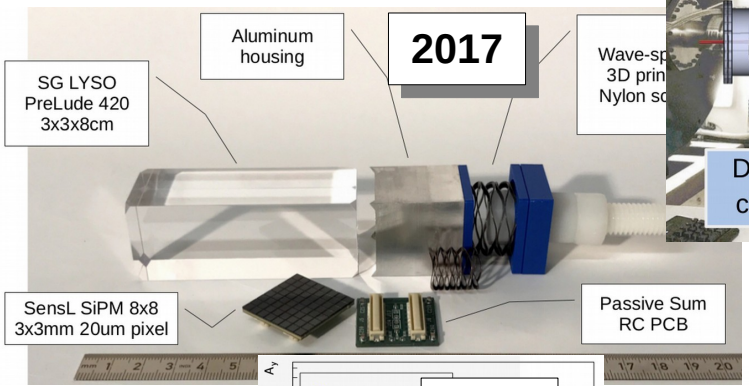
- Mechanics: N. DeMary, M. Maubach, G. D'Orsaneo & D. Spölgen
- Electronics: Tanja Hahnraths-von der Gracht & T. Sefzick
- DAQ & FEE: D. Mchedlishvili, & P. Wüstner
- G4: **H. Jeong (PhD)** , G. Macharashvili, & N. Lomidze
- **Ms.: O. Javakhishvili, G. Kvantrishvili, M. Gagoshidze, & D. Kordzaia**
- **PhD: F. Müller, D. Shergelashvili, & S. Basile**

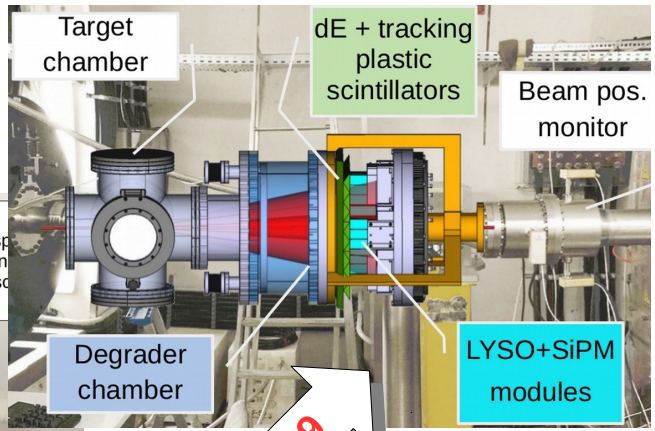
PROGRESS SINCE 2016



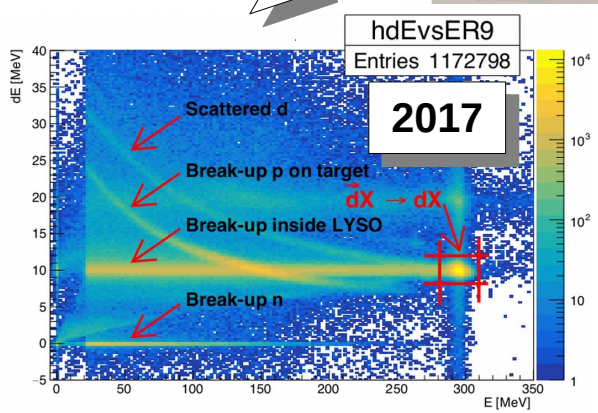
2016

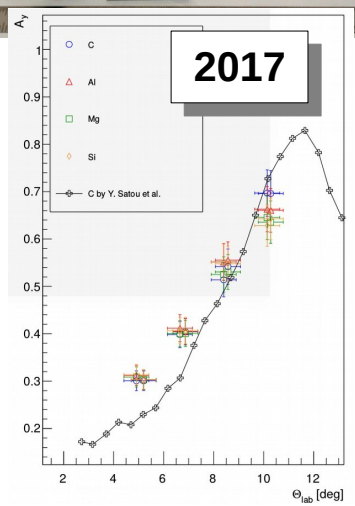
JEDI Polarimeter

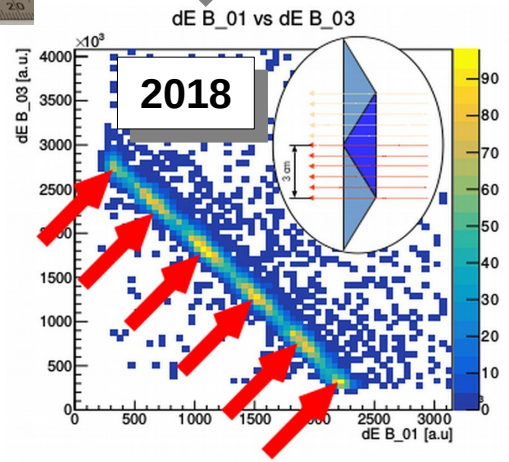




2019

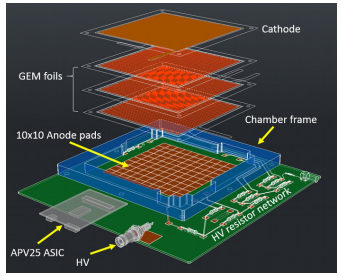




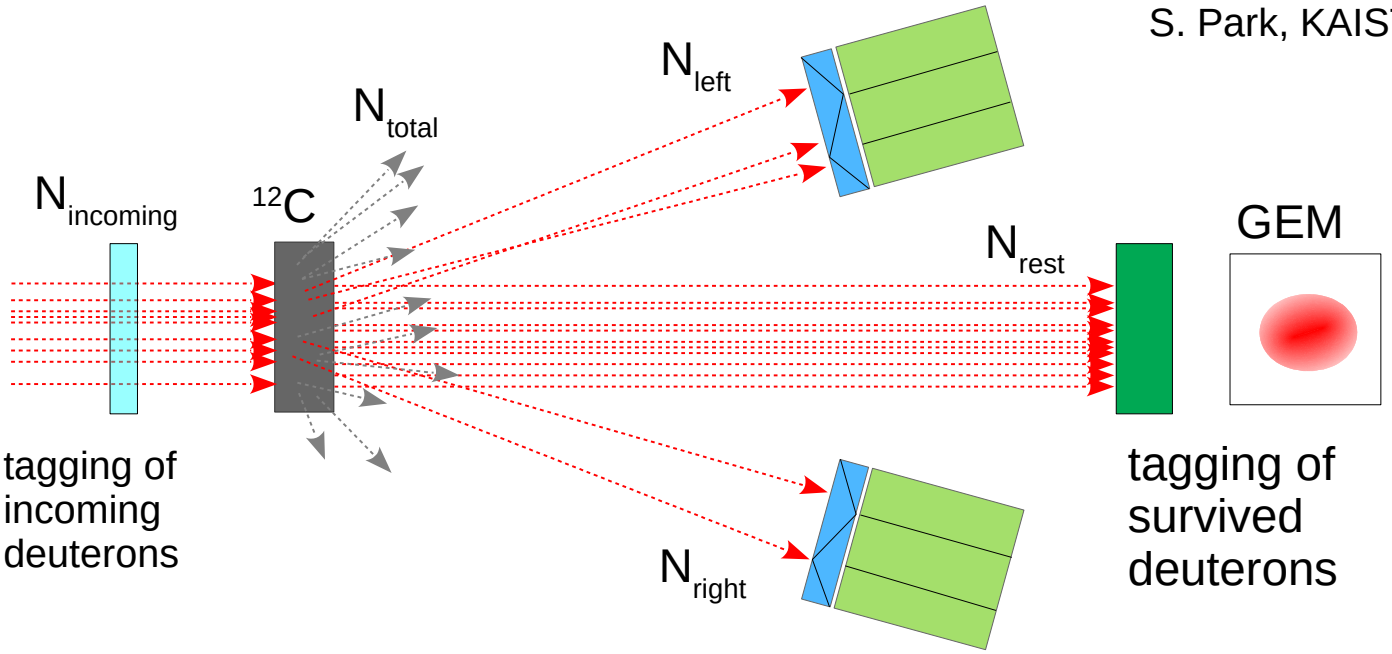


TOTAL CROSS-SECTION

$$N_{lost} = N_{scattered} + N_{dE} + N_{acc}$$

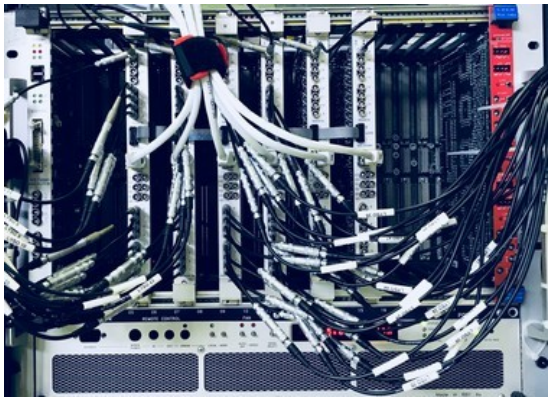


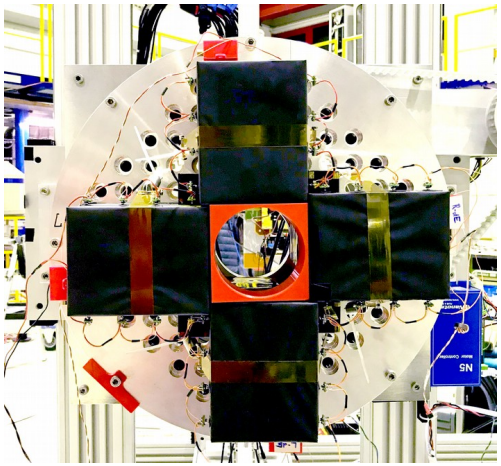
S. Park, KAIST

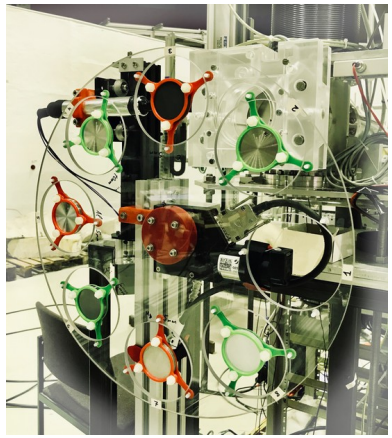


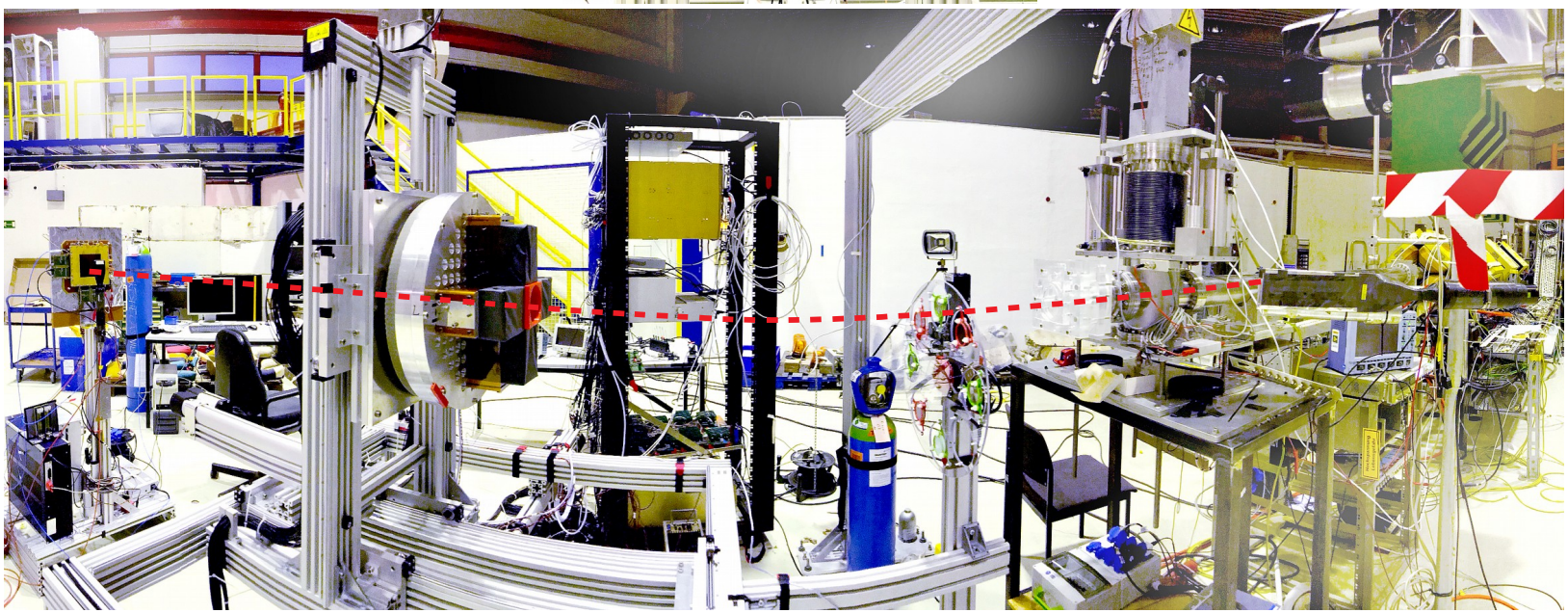
$$N_{scattered} = L \times \sigma_{tot} = N_{el} + N_{inel} = N_{incoming} - N_{rest}$$

BIG KARL EXP. HALL

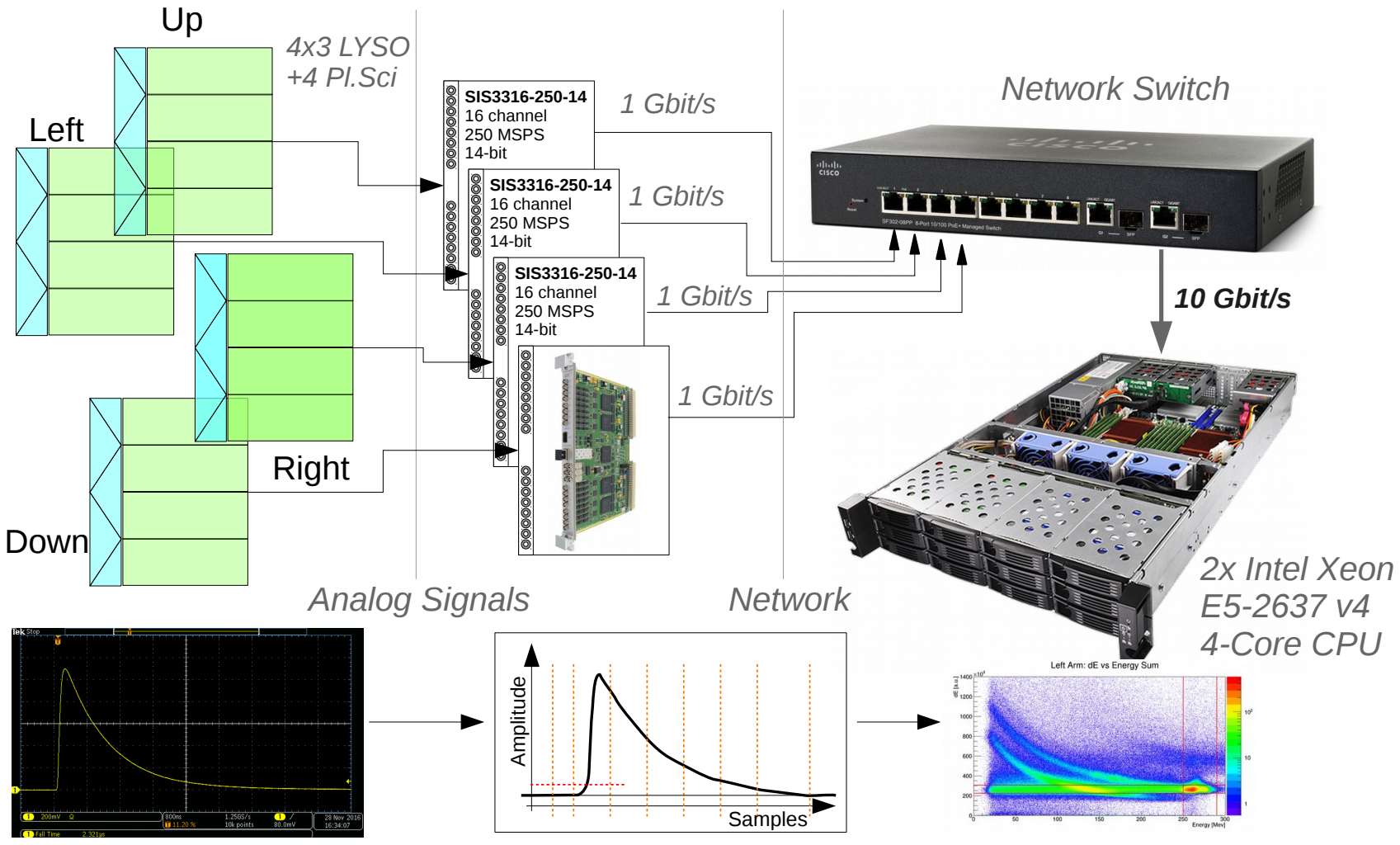








SADC BASED DAQ SYSTEM



SIGNAL SHAPES

Full signal shape vs 8 accumulator/integral region